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ABSTRACT

Computer-based information search services (ISSs) of the type that provide online literature searches are analyzed from a systems viewpoint using a continuous simulation model. The methodology applied is "system dynamics," and the system language is DYNAMO. The analysis reveals that the cbserved growth and stagnation of a typical ISS can be explained as a natural consequence of market responses to the service together with a business orientation on the part of the funder. An analysis of managerial decisicn-making is also presented, and implications for the aggregate information search market are explored. It is claimed that the growth pctential has been overestimated and that a decline in the aggregate growth rate is likely, though not inevitable. (Author)

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THE DYNAMICS OF INFORMATION SEARCH SERVICES

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CHAPTER FOUR
AN EXPLANATION OF THE COMING STAGNATION OF INFORMATION SEARCH SERVICES

FOREWORD

This report is the account of a project aimed at investigating marketing aspects and managerial decision making for information services of the kind that provide on-line searching of scientific and technical bibliographic information. These services will henceforth be called information search services, or ISS's.

The project has been supported by the Swedish Council for Scientific Information and Documentation (SINFDOK).

Findings from the project have been presented in the following reports and papers (acronyms to be used in this report are given in parentheses):

(DMISS) Lindquist, M. G., "Dynamic Modeling of Information Search Services - A Simple Resource Allocation Model", WP 862-76, Sloan School of Management, M.I.T., Cambridge, Mass., June 1976. Also available as report 7€2063, The Swedish Council for Scientific Information and Documentation, Stockholm, 1976.

(GDISS) Lindquist, M. G., "Growth Dynamics of Information Search Services", report TRITA-LIB-6009, The Royal Institute of Technology Library, Stockholm, November 1976. (Abridged version to appear in JASIS).

(ECSISS) Lindquist, M. G., "An Explanation of the Coming Stagnation of Information Search Services", On-line Review, v. 1, n. 2, (June 1977), pp. 109-116.

In addition, an overview of the project has bees presented at the 1975 annual meeting of the American Society for Information Science, ASIS:

Lindquist, M. G., "Dynamic Modeling of Information Services - Project Overview", Proc. ASIS, v. 12, pp. 43-44.

The present report consists of four chapters:

- Chapter one, Description of the Research Project, gives the background for the study and a discussion about theoretical foundations and methodology. The main results are presented, and general conclusions from the study are drawn.

  Chapter two, Growth Dynamics of Information Search Services, is a revised version of GDISS, pp. 1-32.

  Chapter three, ISS2 Model Description - A Theory of ISS Growth, is a rewritten model description that builds on the description in GDISS (pp.35-62).

  Chapter four, An Explanation of the Coming Stagnation of Information Search Services, is the paper ECSISS, reprinted by permission.

Many people have helped me in many ways to bring this study to a conclusion. It is my pleasure to thank them.

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While at the Sloan School of Management of the Massachusetts Institute of Technology my initial modeling efforts were guided by professor Edward B. Roberts. His help and encouragement are appreciated.

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I have received much cooperation and help from the staff of existing ISS's which have been valuable for the model formulation. I want to thank Roland Hjerppe of the RITL-IDC (Stockholm) and Mary Pensyl of NASIC/MIT especially.

In stockholm professor Börje Langefors has been my thesis advisor. His persistence in not letting me get by with half-thought ideas has improved my dissertation very significantly. I appreciate this guidance.

Since I started the write-up of the project I have benefitted from my interactions with the 3RIP-group, later to form the Paralog AB company. I want to thank Mats Löfström, Christer Bryntesson, and Rolf Larsson. Their general support and 'Då bestämmer vi det's have not been without effect.

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Stockholm 1978-02-27

M. G. L.

CHAPTER ONE
DESCRIPTION OF THE RESEARCH PROJECT

I. INFORMATION SEARCH SERVICES

Indroduction and Background

The growth in the volume of scientific and technical information has followed an exponential path since the middle of the eighteenth century and has now reached a level of over 100 000 published journals. The need for efficient procedures for searching and accessing the body of recorded knowledge has increased accordingly and resulted in a number of changes in these procedures.

The traditional depositories for literature are libraries and the traditional access tools are the library catalogs. As long as the volume of the literature in a particular scientific field was small it was possible for a special library to have a comprehensive collection and a search in the local cataloge could give satisfactory answers to "what and where" questions about scientific information. The first attempts to cope with the growth of information volume therefore, naturally, involved changes in the cataloging procedures. As early as the middle ages cataloging procedures began to change towards control of the actual documents, whereas before that, the primary goal was to provide control of their content (Battacharyya, 1974) - a change that seems to be a response to an increase in volume. Later, when it became impossible for one library to acquire all the relevant literature in a field, cooperative agreements between libraries were developed and union catalogs provided the answers to "what and where" questions. Library cooperation was, however, not sufficient to cope whith the growing volume of literature, and patrons of the cooperatives could not get exhaustive answers to their "what and where" questions. One part of the problem is that library collections in general are growing slower that the literature: a typical doubling time for library collections is close to 20 years (Baumol & Marcus, 1973) whereas that for the scientific literature is 15. The other part is due to structural changes in the scientific literature. From earliest days to the present there has been a trend towards more specialization which has been reflected in a more detailed subdivision of the literature. The consequence for the libraries has been that two libraries whith a slightly different subject orientation can end up having substantially different collections whith increased difficulties for the patrons to locate the literature of interest. At the same time as there is a trend towards more specialization there is also a trend towards interdisciplinarity (Rozsa, 1973) which further reduces the chances of any one library being able to give exhaustive answers to "what and where" questions.

The problem of logical access to the literature was further enhanced by the increased importance of the journal article as the vehicle for disseminating scientific knowledge since the traditional library catalogs do not go deeper than to the level of journal volumes. Secondary journals, or abstract journals, were published in response to this need. These journals were published by learned societies or professional associations and contained abstracts and source information about articles in the primary journals of interest. They began to appear around 1840 and their number has been growing exponentially, at the same rate as the number of primary journals, since the latter part of the nineteenth century (see Figure 1).

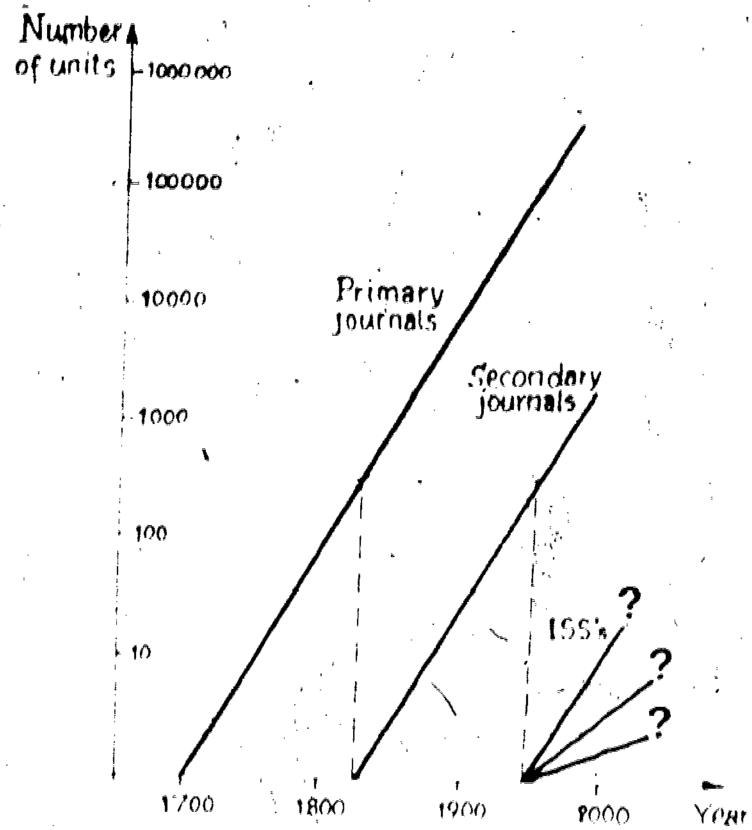


Figure 1

Growth of primary and secondary journals, and possible growth paths for ISS's (after DeSolla Price, 1961)

Considering the continued growth in scientific information, it is easy to realize that the publication of secondary journals was but a temporary solution to the problem of detailed logical access to the scientific literature. At present we can see a number of approaches to alleviate this problem by applying computer technology (Knox, 1973). These computerized information services use machine-readable versions of abstract journals or specially produced data bases containing bibliographic information and a description of content ranging from keywords to abstracts. The service provided by these "Information search services", ISS's, is to provide a list of literature references, sometimes with an abstract of summary, in response to a query from a user.

In the ideal case an ISS provides access to "the worlds's" scientific and technical literature but in reality the coverage of the literature is constrained in many ways. Often an ISS is set up with a particular market in mind, either on the basis of subject specialization or organizational constraints.

From about 1960 to the early 1970's the main function of the ISS's was to provide a "current awareness" service, also called Selective Dissemination of Information (SDI), primarily based on printed secondary journals. The users of these services subscribed to searches by submitting an interest profile which was matched against the periodically issued data base. The resulting list of references was then mailed to the user. The relative success of the SDI-services, together with the fact that machine-readable information bases were accumulating, motivated attempts to provide retrospective search services. For the users this meant that a new interest or search profile could be matched against the accumulated data base and not only against forthcoming additions. The main probelm was to find economically feasible ways of processing the voluminous information. Decreasing costs for information storage and for telecommunications made it possible to experiment and develop systems for these retrospective search services. Today the principal effort in the documentation field is to develop further the retrospective search capability using on-line computing technology and to find economically and organizationally reasible structures for ISS's.

There are parallels between the development of ISS's and the introduction of secondary journals in the 1840's, and it is interesting to note the symmetry in Figure 1. It is still to early to make projections for long term growth since the number of ISS's is dependent on many other factors, such as computing and communication hardware, library networking, and the structure of the publishing industry.

Organizational Settings

Information search services are costly. Development costs for a comprehensive search system is of the order 1 - 3 million dollars. The generation of the data bases requires much intellectual work: evaluation, sifting, analysis, and sometimes indexing. Data base maintenance is a complex operation since indices have to be updated at the same time as the data base itself. Access to the ISS requires terminals and other communication equipment, and although its cost is rapidly declining it is still high.

The cost structure is characterized by high fixed cost and low variable cost. The former is due to the advanced technology required and the size of the databases; typically more than half the total computer charges is for data base maintenance and storage (Larsson et al., 1976). The low variable cost is due to the intrinsic efficiency of modern computing and communication equipment (compared to the information processing capabilities of humans). With this cost structure it is natural that "utilization", or "business volume", is central to any study of ISS's.

The utilization of ISS's is growing but is still not high enough considering the high costs. There is a substantial reliance on subsidies of various kinds. The typical ISS is part of a larger organization, e.g. a library, and receives revenue through the budgeting process of that organization.

The economics of information search services has contributed to the development of a market structure which consists of relatively few service suppliers, or wholesalers, and a larger number of ISS's, or retailers, (Gardner, et al., 1974). The "users" of an ISS are the end-users of the information, e.g. an individual scientist or engineer. In some cases, however, the service supplier "sells" his service to an organization as a whole for in-house use. We can design two ideal models for the delivery of information search services: the "public" service and the "in-house" service. To clarify the organizational setting for the typical ISS it can be useful to discuss the differences between the two ideal models. It should be noted that it is not the information search service per se but the organizational context which determines which is the appropriate model for studying the utilization of the system.

For an in-house service the number of users is more or less fixed and the growth criterion is the number of queries (or accesses to the system). The primary performance constraint is not strictly economic since the decision to acquire the right to access has been made and there is not hope of passing the costs to other accounts. There is, however, an implicit cost consideration in the assessment of the utility gain from the system.

For a public service, i.e. the ISS's that are the object of this study, the growth criterion is the number of users since this is the prime determinant of the volume of business. There is usually an eco-

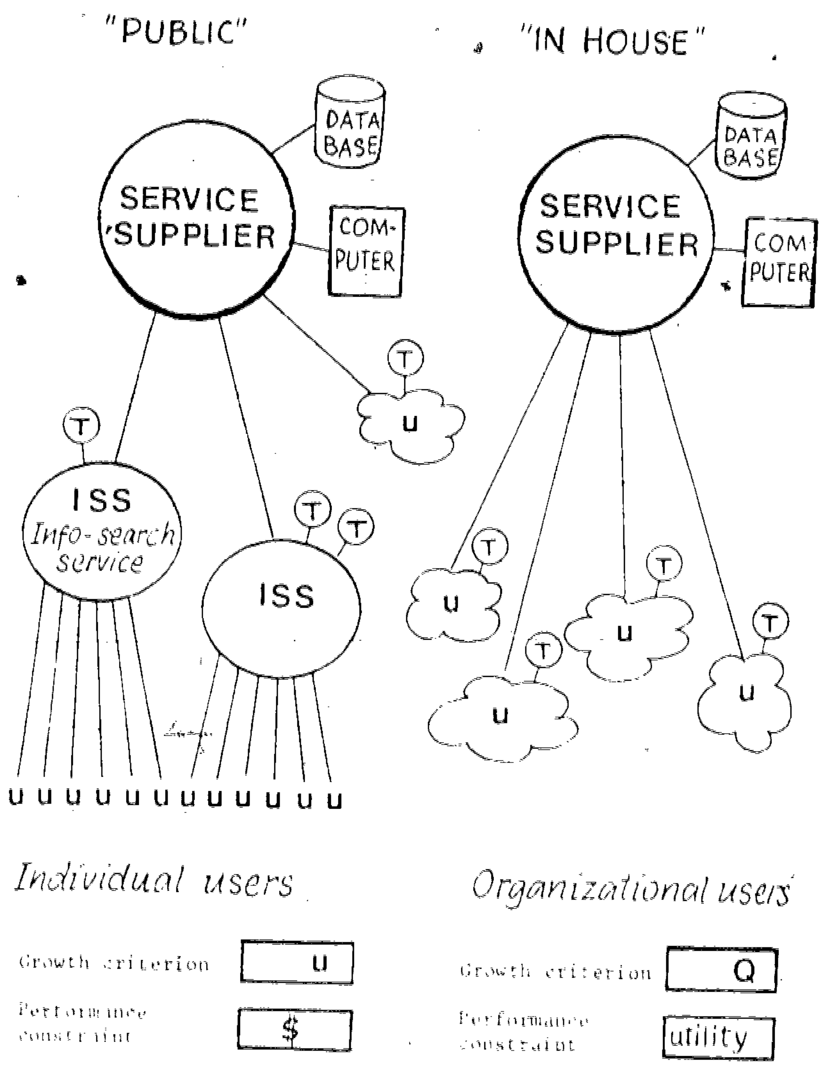


Figure 2
Organizational settings for ISS's

nomic performance constraint (Schwarz, 1976 and Gardner et al., 1974), which can be explained by the fact that the users normally are frome outside the department retailing the service, even though they typically belong to the same sperordinate organization.

The two models are illustrated in Figure 2.

The Structure of an ISS

To illustrate the structure of an information search service we can relate its functions, in terms of "machines", to the overall activity of user access to the scientific literature (Figure 3).

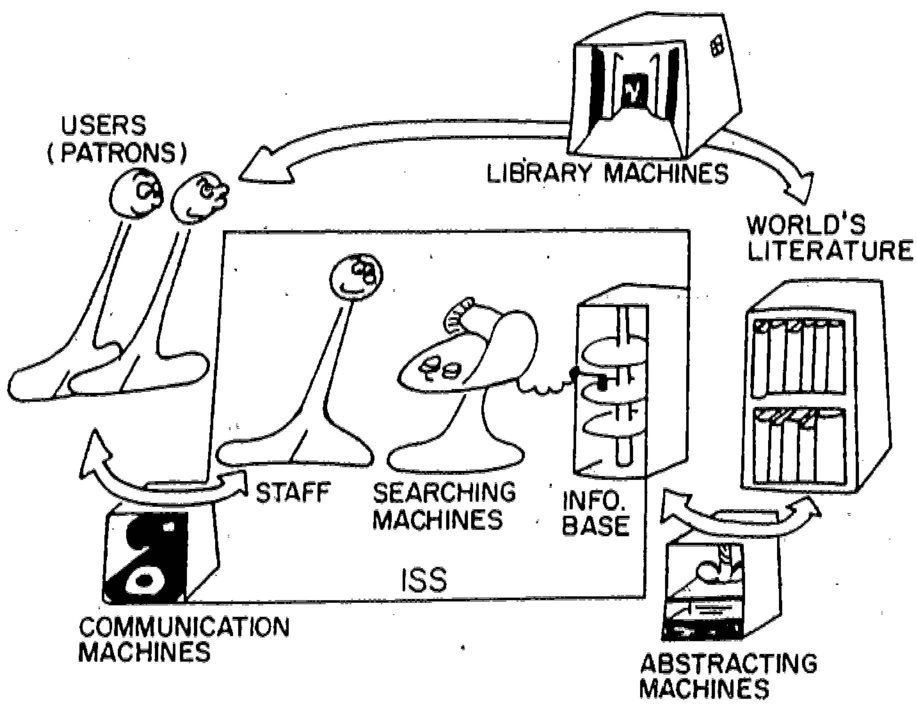


Figure 3
The structure of an ISS

The function of the library machines is to locate a specific document and make it available to the user. The function of the abstracting machines is to create a machine-readable description of documents, including a description of the content. For the purposes of this study we assume that the operation of these two types of machines is done by organizations other than information search services.

The function of an ISS is to respond to a query, or search request, from a user by performing a computerized search in the information base to locate literature references of relevance to that request.

The language used by the abstracting machines is different from that of the typical user and the first task for the ISS staff is to translate the user's search request into the appropriate query language. This process can be described as finding the appropriate key-words or search terms. In an on-line environment this process is usually done in stages, so that intermediate search results are, at least partially, displayed and evaluated and on basis of this evaluation the search statement is modified. It is, however, important to have the user be specific about his search request, and typically he is asked to submit his request in writing. These written search requests are analogous to orders in a manufacturing firm, and they are subject to two primary scheduling delays: the subject specialty of the request is matched with the subject competency of the ISS staff and with the coverage of the available data base. The latter matching introduces a delay since, because of storage limitations on part of the information supplier, it is common to make only part of the total information base available at any one time. System down-time adds to this delay.

In all on-line information search services the delays due to scheduling and distribution exceed the actual search time at the computer terminal by several orders of magnitude.

The actual role of the ISS staff varies: in some cases the staff carries out the searches, either with the user present or alone, and in other the user does the actual searching with the staff member coaching. In either case the output of the ISS is dependent on the staff resources available.

II. THEORETICAL FOUNDATIONS AND METHODOLOGY

Underlying theories

A study of information search services and their growth must, like any other study that involves customers and their interactions with the service or business, rest on theories of customer behaviour. In the following a discussion will be given that explores the two factors that attract users to the service and how the users respond to a decline in the quality of the service.

To describe the factors that attract users to the service the needed theory is one of the determinants of sales. Price and quality are the two most commonly studied determinants but in dynamic analyses delivery delay is often studied explicitly. It is possible to include delivery delay in either price (by introducing out-of-stock cost) or quality (by having "speed" or "availability" as a dimension of quality) but sometimes this is not desirable.

The problems relating to pricing of information and documentation services have received some attention in the literature and in policy making bodies. There is, however, evidence that price is not a primary determinant of sales.

In a Swedish study of price as a policy tool for technical information and documentation services (Gustafsson, 1976) it was found that price is likely to be of secondary importance provided the service is seen as useful by the consumers.

There has been little direct experimentation with price changes but indirect evidence can be found in analyses of the effects of changes in price for SDI-services.

Hjerppe (1977) reports that when the price of the IDC service was raised 50% subscriptions dropped only 8% which indicates a low price elasticity. The same conclusion can be drawn from Zais' (1976) thesis, where an example is cited (p 91): for the Dow Current Awareness Service the price elasticity of demand was found to be 0.19. The elasticity measure used was the percentage change in quantity resulting from a 1 percent change in price.

For on-line services there is no evidence to indicate that price should be a crucial factor (Tomberg 1977 b); when the American corporations Systems Development Corporation (SDC) and Lockheed Informations Systems (LIS) could make their services readily available in Europe they experienced an increased demand even though they introduced a significantly higher price.

A further illumination of the influence from price on buying can be obtained by looking in more detail on the findings from a Wharton School study (Wind et al., 1976). This study was conducted to assess the relative importance of various characteristics for systems providing informations search services, as perceived by 274 scientists, information specialists and managers. The implicit decision situation for the persons interviewed was acquisition of service, which is not equivalent to the decision to use the service but the study can give some general indication of the importance of price.

One of the results from the study was: "Price is the most important determinant of the purchase of an STI system. Yet, the major disutility is associated with the very high price level. The move from the cheapest level to the medium-low level (for example, from $ 30 to $ 50 per inquiry) is associated with a disutility of 1.54, which can be easily compensated for by a number of factors - such as changes in the period coverage, mode of distribution, and the like."

In other words, price is important since it can scare users away. However, within the given market price is not a dominant determinant of sales. A further analysis of the responses shows that only 31% of the study population had price as the most important factor, and the largest "utility segment", which was 48% of the population, gave price a relative importance of only 8.9%.

The operational ISSs we are studying here are in the high price region, and the options open to the ISS management are very limited when it comes to pricing (see discussion in Chapter two). Based on these considerations price is not considered a primary determinant of sales in the present study.

The SDC and LIS experience of the introduction in Europe seem to indicate that quality might be a more important determinant of sales. The same is implied in a number of reports and papers; Wish and Wish (1975), referring to information service centers, is an example:

> "In marketing a service, the job is essentially, that of making the clients aware of their needs, if they aren't already, and, most important, being ready to take care of those needs with quality performance". (p. 3)

Quality, however, is not a well defined property and a decomposition is necessary before its influence on sales can be analysed. The dimensions for quality can be inferred from Hjerppe and Lindquist (1971), which has been the basis for the more detailed illustration given in chapter two (p 71 ff). Some components of quality depend on the machinery used, i e search systems, data bases, and telecommunications equipment, while others depend on how the service is delivered locally, i e how the staff interacts with the users.

For the present study it is important to distinguish between components of quality that can be assumed constant and those that are variable, since they require different representations: the effect of a constant quality component can be accounted for by some kind of parameter whereas the effect of a varying quality component must be represented in a more complex way.

As discussed in chapter two (p. 84) the ISS managers have limited possibilities to affect the quality of the service as far as content of data bases and form of output goes because of the retailing character of ISSs. For the established services the system changes that would affect these quality components are relatively slow.

The contribution to quality provided by the staff in its interaction with the customers is important, especially when the customer has no previous experience from an ISS (Benenfeld, 1974 and Persson & Höglund, 1975). Since the amount of assistance that can be given is dependent on the staff time available this quality component can vary considerably. If staff turnover were high it would perhaps be necessary to take the effect of staff training into account, but this is not the case for the typical ISS.

Staff time available also determines the response time of the service, which is an important component of quality (Llewellen & Kaminecki, 1975; Wanger et al., 1976, p A-6). The response time is also a direct function of the "load" on the system, i e the number of users and their demand. Consequently it can also vary considerably.

The conclusion from the discussion of quality as a determinant of sales is that it is not possible to represent the influence of quality in a simple way, since quality is not easily measurable but depends on factors that are interrelated.

When discussing the determinants of sales the implicit assumption is that the only decision the customer makes is whether or not to buy the product or service, alternatively to remain a user or to leave the service. Hirshman (1970) in his analysis of responses to decline in firms, organizations, and states considers this a characteristic viewpoint of economists:

> "The customer who, dissatisfied with the product of one firm, shifts to that of another, uses the market to defend his welfare or to improve his position; and he also sets in motion market forces which may induce recovery on the part of the firm that has declined in comparative performance. This is the sort of mechanism economics thrives on. It is neat - one either exits or one does not; it is impersonal - any face-to-face confrontation between customer and firm with its imponderable and unpredictable elements is avoided and success and failure of the organization are communicated to it by a set of statistics; and it is indirect - any recovery on the part of the declining firm comes by courtesy of the Invisible Hand, as an unintended by-product of the customer's decision to shift". (pp. 15-16)

The opposite of this "exit option", as Hirshman calls it, is the "voice option" which has been studied primarily by political scientists and sociologists, mostly within frameworks which do not include economic considerations.

The two options are defined as follows:

1) "Some customers stop buying the firm's products or some members leave the organization; this is the exit option. As a result revenues drop, membership declines, and management is impelled to search for ways and means to correct whatever faults have led to exit.

2) The firm's customers or the organization's members express their dissatisfaction directly to management or to some other authority to which management is subordinate or through general protest addressed to anyone who cares to listen: this is the voice option. As a result management once again engages in a search for the causes and possible cures of customers' and members' dissatisfaction". (p. 4)

Hirshman argues that in many cases both options are available to, and exercised by, customers of commercial firms or services.

Considering that ISSs do not operate in a market economy and that they show resemblances with membership-type organizations (e g a particular university community) - both factors which encourage voice - we adopt Hirshman's theory as one basis for describing user behaviour. Specific features of the organizational setting of ISSs which support this theoretical viewpoint are: 1) The monopoly-like character of an ISS. There are usually no real competitors - it is sometimes said that the worst competitor is "no-use". 2) A partial membership characteristic of the consumer market. As was pointed out earlier an ISS typically belongs to a larger organization, and the users of the service have some kind of affiliation to that organization. 3) Existence of voice channels. Firstly the interaction between ISS and user is personal which makes it easy to use voice, and secondly ISSs often try to solicit evaluative feedback from their users on questionnaires or in some other formalized way.

Empirical basis for the study

We have found that for a study of ISSs there is a need for information about effects that are not easily measurable. In particular quality is difficult to measure and must be analysed in a more complex way.

The information sources available do not, however, give much information directly suited for such a complex study. The difficulties encountered when trying to utilize published statistics from operational ISSs are shown in the following discussion.

Operational ISSs are relatively new. Although on-line retrieval systems have been established since about 1968 a System Development Corporation study (Wanger et al., 1976) shows that existing information services (ISSs) on the average have been in operation only a couple of years. So the information base for a study of ISSs is fairly small, a problem which is worsened by the lack of measurement standards and established definitions. In particular such key variables as "users" and "queries" can mean a number of things. This is indirectly a consequence of the market structure discussed earlier: the data base producers impose different conditions for the availability of their data base, primarily different royalty structures, and the service suppliers pass on these differences to the ISSs. Aiming at a cost-related pricing the ISSs are forced to keep separate accounts, which in some cases will lead to a user's search request being counted as several queries. Unless a detailed log is kept he could then also be counted as more than one "user". If several users interact with the ISS through one representative, either out of practicality or billing necessity, they are seldom counted separately. To an extent, then, the difficulties involved in analyzing available numerical information stems from the fact it is collected primarily for the bookkeeping functions of an ISS and not for the managerial functions.

Descriptive, qualitative, information about ISSs is available from a number of sources: annual reports and other operational statements, conference proceedings, and journal articles. Often this information consists of subjective accounts of experiences from ISS operations. Study visits and correspondence are other sources of this kind of information.

These information sources also contain some quantitative information about the ISS operations and performance, but the definition of variables and their measurement vary from case to case. Problems such as these are not unique to studies of ISSs: Stouffer (1962) characterizes the data of social science as extremely complex, and they "involve values that sometimes put a strain on the objectivity of the investigation" (p. 291), and Kaplan (1968) notes that often measurements are made for other reasons than scientific inquiry. The present study is an example of this as discussed above.

Lack of well defined numerical information does not however, mean that a scientific inquiry is impossible. Glaser and Strauss (1968) for example, advocates an approach to theory building that is based on descriptive information rather than conventional "data" collection.

Taking the advocacy of Glaser and Strauss as a starting point, we can explore further the possibilities of constructing a theory about ISSs given the relatively unstructured character of the empirical evidence available. In the following we will let "data" denote information that has been coded according to some well-defined scheme; usually such a scheme is based on a numerical scale but classificatory schemes are sometimes used. We begin by discussing scientific theories in general and then look at the relationship between theory and data availability.

We adopt Brodbeck's (1968) definition of a theory as a deductively connected set of empirical generalizations: it is possible to refute theories and they are thus hypothetical. Theories are constructed, and the way this is done is in essence the content of the works by Popper (1968), Kuhn (1962), and Blalock (1969). Kuhn takes a political macro perspective on the process, Popper a philosophical, and Blalock a practical. A theory can be assessed according to several criteria: robustness, generality, replicability, precision, usefulness, and others. Popper discusses the properties of a good scientific theory, and sums up the discussion (p. 37): "the criterion of the scientific status of a theory is its falsifiability, or refutability, or testability". This gives some implications for the relationship between theory and problems (to be subject to scientific inquiry): if a theory is made too general it will almost always be true - such a grand theory escapes falsification but at the price of destroyed testability (and also their explanatory power is small). Merton's (1957) and Zetterberg's (1965) advocacy for "theories of the middle range" can be seen in this context, even though part of their concern relate to data collection. Stouffer (1962) brings in another constraint, that of limited resources available for the inquiry. This in turn relates to the recognition of the subjectivity of theory construction: it is a creative act by people. And since theories are some form of generalizations of (a perceived) reality the subjectivity of observations follows.

Weber (1968) states that an objective analysis of cultural events is an impossibility, and that all knowledge of cultural reality is always "knowledge from particular points of view" (p. 92).

Thus we see things (observations) but what we see is a function of our point of view (like a theory), and we might pursue the question of which comes first. Popper's reply is that the observation comes before the hypothesis but is preceeded by an earlier kind of hypothesis (p. 47).

Glaser and Strauss (1968) see the connection between theory and data as not always desirable: "theory based on data can usually not be completely refuted by more data or replaced by another theory... it is destined to last despite its inevitable modifications and reformulations". (p. 4).

Another problem that has a bearing on the relationship between theory and data is described by Kaplan (1968) as a "choice between mapping his data into a simple order and asking his data whether they satisfy a simple order" (cf. multidimensional scaling). Popper (1962, p. 46) looks at the same phenomenon from a general viewpoint and states that we try to discover similarities in the world and to "interpret it in terms of laws invented by us". This view is also essentially what Kuhn characterizes as the way "normal science" work.

Taking these different aspects of the interrelationship between theory and data into consideration we can conclude that it is possible to construct a scientific theory even though there is not much well defined numerical information available.

The impact of data availability on theory construction can be summarized:

- A "data-bound" philosophy of theory construction will limit the options for theory building, but the resulting theories can, if the variables are selected properly, have higher usefulness since optimizations are possible.

- A data-free approach has the advantage that by ignoring the problem of data availability it can address relevant problems in explanatory theories.

Another difference between the two approaches is what procedures there are for increasing confidence in the theories. For a theory that is constructed from data the normal procedure is to apply statistical procedures, and to secure adequate and proper data, i.e. choose an experimental design that controls external factors (Campbell and Stanley, 1966). It should be pointed out that the statistical (probabilistic) model of uncertainty is not the only possibility: Schweppe (1973) presents a model in terms of "unknown but bounded" variables, and the theory of "fuzzy sets" is another. These other mothods have, however, not yet the same developed apparatus for hypothesis testing but deserve mention as possibilities.

For data-free theories the established statistical procedures cannot be used to increase confidence, which is a drawback when it comes to "marketing" the theory. However, the more important aspect of refutability of the theory still remains, since the theory could be shown to be false by further observations.

Given these considerations regarding the available empirical basis and the relationships between data and theory we believe that it is possible to make a valid scientific inquiry into the behavior of ISSs, and it is the research hypothesis of this study that the inquiry can be done by using the system dynamics methodology (Forrester 1961 and 1968).

System dynamics modeling as a scientific activity

System dynamics is a vehicle, or a methodology, for theory construction and it shows great similarities to the "hypothesis method" for scientific inquiries in the natural sciences (Hempel, 1972): the goals of a system dynamics study is to analyze an observed phenomenon and give a deeper understanding of its underlying processes, and to make it possible to make predictive statements regarding the phenomenon - these goals correspond to the characteristics of a good theory given by Hempel (1972, Chapter 6.3). When the study is of a system subject to human decision-making this last aspect is pursued to arrive at recommendations for improving the performance of the system.

A scientific inquiry is a process characterized by parallel activities and iterations. We have already discussed the interplay between theory and data: how one tries to explain observed phenomena with theories, and how theories determine what is observed. The hypothetical nature of theories does not change even though their content might change. A theory is a set of interrelated hypotheses and as the scientific inquiry progresses the set will change: preliminary hypotheses are formulated to guide information gathering (observations) and are rejected or modified if they do not lead to an acceptable explanation of the phenomenon being studied. Analogously it holds true for system dynamics modeling that the process is characterized by iteration between observation, model formulation (hypotheses), and simulation runs (tests). "When a system theory takes shape as a simulation model, its behavior precipitates more discussions and brings out additional supporting and contradictory information that helps refine the theory" (Forrester, 1969, p. ix).

Different types of hypotheses are formulated in a system dynamics study (Mashayekhi, 1976).

a) Reference behavior. A system dynamics study starts with what is called a "reference mode of behavior", i.e a description of a problem in terms of how system variables develop over time. When the time horizon for the description of the reference behavior is in the future, as was the case in the study Limits to Growth (Meadows et al., 1972), the reference behavior is a hypothesis. The same is true when the description is of variables which have not hitherto been observed, or which are not possible to study directly (see next point).

b) Boundary hypotheses. When the boundary for the model is drawn implicit assumptions about what is relevant for the study are made. These assumptions are sometimes based on established empirical knowledge but are often hypothetical.

c) Structural hypotheses. Sometimes hypothetical relationships between variables must be formulated as part of the model building, for example of the type "an increase in A leads to an increase in B" where A and B are variables in the model. Earlier studies might have omitted certain relationships, or even important variables, so there might not be any established empirical knowledge, on which to build.

d) Hypothetical parameter values. The same reasoning as for the relationship between variables can be applied regarding parameter values.

Regarded as a theory a system dynamics model can contribute to a generalization of earlier knowledge by providing a unified description of different occurences of a phenomenon. The model can also make earlier knowledge more detailed by showing under what circumstances earlier explanations are valid. It is often true that when a deeper understanding of a phenomenon is achieved, "truths" turn out to be "half-truths".

A system dynamics model, like simulation models in general, can also increase the scope of existing knowledge since it is possible to simulate changes in the model. Sometimes this is not even necessary: a thorough analysis of the simulation results can both point out and explain aspects that were previously unobserved.

From this discussion it seems that system dynamics can be used to study complex problems and give increased knowledge about the phenomena in question. In particular we find it reasonable to assume that system dynamics modeling is an appropriate methodology for making a scientific inquiry into the behavior of information search services.

The process of formulating a simulation model can be described as follows. A phenomenon is observed and studied and preliminary hypotheses are formulated. Regarding structural hypotheses and hypothetical parameter values it is primarily a question of inductive reasoning: the goal is to find something resembling a general law. The preliminary model is tested by deductive reasoning: if the model is valid the results of the simulation run must resemble the observations of the real system. That the model will reproduce the "reference mode of behavior" is the minimum requirement. In addition the validity of the model must be tested in some way. There are no established norms for how this should be done. The appropriateness of different tests depends on the character of the problem or phenomenon: if one wants to explain instabilities it could be appropriate to subject the model to noise or step function inputs, which is not directly relevant when one is studying long term growth problems. In either case one should examine how the behavior of the model is changed by changes in parameter values to make sure that the simulation results are not the consequence of a "fortunate" combination of parameter values in an "incorrect" structure.

The model is tested and refined, i. e. the preliminary hypotheses are changed, until the model can give an adequate explanation of the observed phenomenon. Criteria for acceptability is a question of credibility, and as for other scientific theories credibility is a function of the scope and character of available facts.

In the cases where the "reference mode of behavior" refers to the future, and hence is an hypothesis, confirmation cannot be made by direct observation. This does not mean that the hypothesis is without empirical content (cf. Hempel, 1972, p. 103), but it can only be confirmed indirectly, i.e. by confirmation of the model structure which generates the behavior. For this type of study a test implication is to "wait and see" and in some cases this can be used for confirmation of the hypothesis.

Examples of hypotheses formulated in the present study are given in Table 1, and sources giving the primary empirical evidence are listed in Table 2.

HYPOTHESES AND THEIR OCCURRENCES IN THE PRESENT STUDY

Reference mode of behavior	Chapter two p. 56 Chapter four p. 180
Structure	e.g. pp. 128-131 (EDDPQ)
(Boundary)	p. 58
Parameters	e.g. 125-127 (perception times)

Table 1

HYPOTHESES AND EVIDENCE FOR ISS2 (Examples)

Reference mode	Brown, 1977 Tomberg, 1977-a Published statistics	 NASIC/MIT RITL-IDC
	SDI statistics	RITL-IDC CISTI UGACC
Structure	Hirshman, 1970 Wanger et al., 1976	
(Boundary)	Llewellen and Kaminecki, 1975 Wind et al., 1976 Gustafsson, 1976	
Parameters	Benenfeld et al., 1975 Hjerppe, 1975 Ljungberg, 1975 Pensyl, 1977 Wanger et al., 1976 Ware, 1973 Published statistics	 RITL-IDC NASIC/MIT

Table 2

The different types of hypotheses discussed above, form an interrelated set, or system of hypotheses, which is illustrated in Figure 4.

This study of ISSs started with an observation that the typical ISS was facing a decline in growth (1), and an hypothetical "mode of behavior" was formulated. Since system dynamics had proved to be of value for similar types of problems, and since its application was convenient, the research hypothesis (2) was that system dynamics would be an appropriate methodology.

Construction of the model involved formulating model hypotheses (3) which were tested by comparing simulation results with observations of reality, both directly and through literature studies. Eventually the simulation experiments led to conclusions (4) which were tested against the model hypotheses and, again, by comparison with simulation runs, i.e. the model hypotheses. In the later stages of the study the conclusions were compared directly with observations of reality. The comparison of the conclusions with the initial reference model of behavior (5) could not be done at once since empirical evidence was not at hand until later.

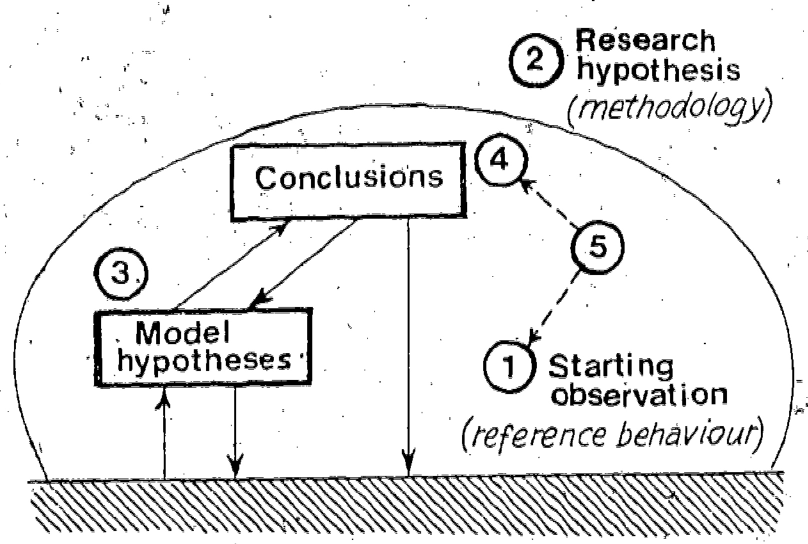


Figure 4

III. ANALYSIS OF GROWTH OF INFORMATION SEARCH SERVICES

A first attempt to explain ISS behavior

As ISSs became established it gradually became visible that they were facing many of the problems that the SDI-services had, in particular it seemed that the growth in business volume was not enough to secure the investments necessary to achieve self-sustainability. One commonly advocated remedy was to spend resources on marketing. However, as was the case for the SDI-services, a concentrated marketing drive usually gave an overwhelming response that the ISS had difficulty absorbing; the result sometimes was that there was a substantial degradation of the service, in terms of response time, which took a relatively long time to compensate.

On these premises the study DMISS was started. The problem to be investigated was that of "insufficient growth", and the working hypothesis was that the problem could be explained by an analysis of managerial policies (DMISS, p. 11), in particular the resource allocation trade-off between marketing and production was investigated. The simulation model ISS1 was developed based on literature studies, study visits, interviews and correspondence with ISS managers. In particular the NASIC/MIT service was consulted.

With ISS1 it was possible to make an analysis of the basic growth mechanism for an ISS. For the case when the ISS resources, primarily staff, are constant the study represents a relevant theory of ISS behavior. Although not a typical situation an ISS is sometimes set up as a research project, or an experiment, with a fixed budget. What seems to be the root of the managerial problem is the different phasing of the users need for assistance and for production, i.e. searching: at first it is relatively easy to give both adequate assistance and response time, but later the ISS has difficulties in keeping the response time short. In other words it seems that by doing the necessary marketing the ISS ends up being overcommitted. Regardless of what the ISS management does at the time it will cause user disappointment in some way (DMISS, p. 47). From the simulations with ISS1 it seems that the size of the potential market is crucial (DMISS, p. 50) - this could be an important decision variable, if it is controllable by management. Regardless, the simulation results raise the question whether the focus on the number of queries, and not on the number of users, gives the appropriate basis for decisions regarding ISSs.

The analysis of the behavior of ISSs when resources are variable using ISS1 as theory (DMISS, p. 52 ff.) gave two general conclusions:

1) that the behavior of the ISS is fundamentally different when resources are made variable (DMISS, p. 61), and
2) for a definitive analysis of ISSs the model would have to be elaborated.

An explanation of ISS behavior

The model ISS2 described in chapter two constitutes such an elaborated model. Further literature studies and study visits revealed that few, if any, ISSs had ambitions to be profit making - rather partial cost recovery seemed to be typical. The problem statement for GDISS is consequently different (see pp. 56-57) and the purpose of the paper is to present an analysis

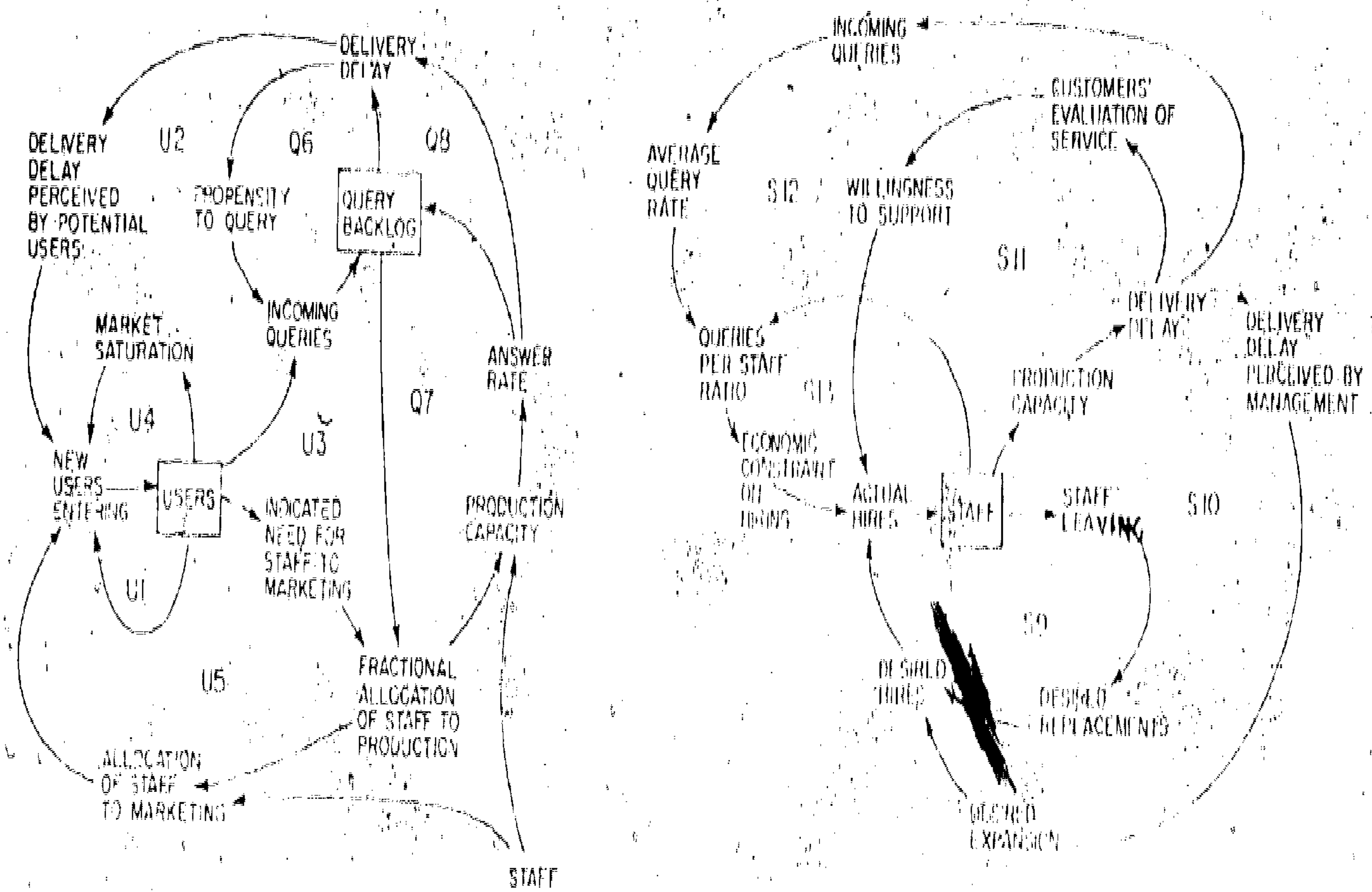


Figure 5
The feedback loops of ISS2

of causes for the growth behavior of ISSs.

The analysis of ISSs, and in particular the analysis of the effects of different parameter values, presented in DMISS represents a test of the basic structure of the ISS/user/funder system, and the construction of ISS2 builds on this test.

In chapter two is presented a systems theory of the ISS/user/funder interactions that determine the behavior of ISSs. The system description consists of a verbal description and figures illustrating the feedback loops involved which are reprinted here (Figure 5). In addition a quantification of the relationships between system variables is needed; this is given in Chapter three of this report.

The quantified model represents a synthesis of information from study visits, interviews and correspondence with ISS managers, and literature sources.

The simulated ISS grows rapidly in terms of number of users for the first 60 weeks, and then the typical decline in growth occurs when the number of users is about 800. From then on growth is significantly slower but the ISS satisfies the funder's economic requirements and is not doing too badly in keeping the delivery delay at the norm so the service expands and has a staff of 4.4 at the end of the simulated time period of 240 weeks. The number of users at that time is 1137, which means a market penetration of 57 percent. The ISS receives 35 search requests, i.e. queries, per week, and the number of new users is 25 per week, which means that the percentage "return users" is 29.

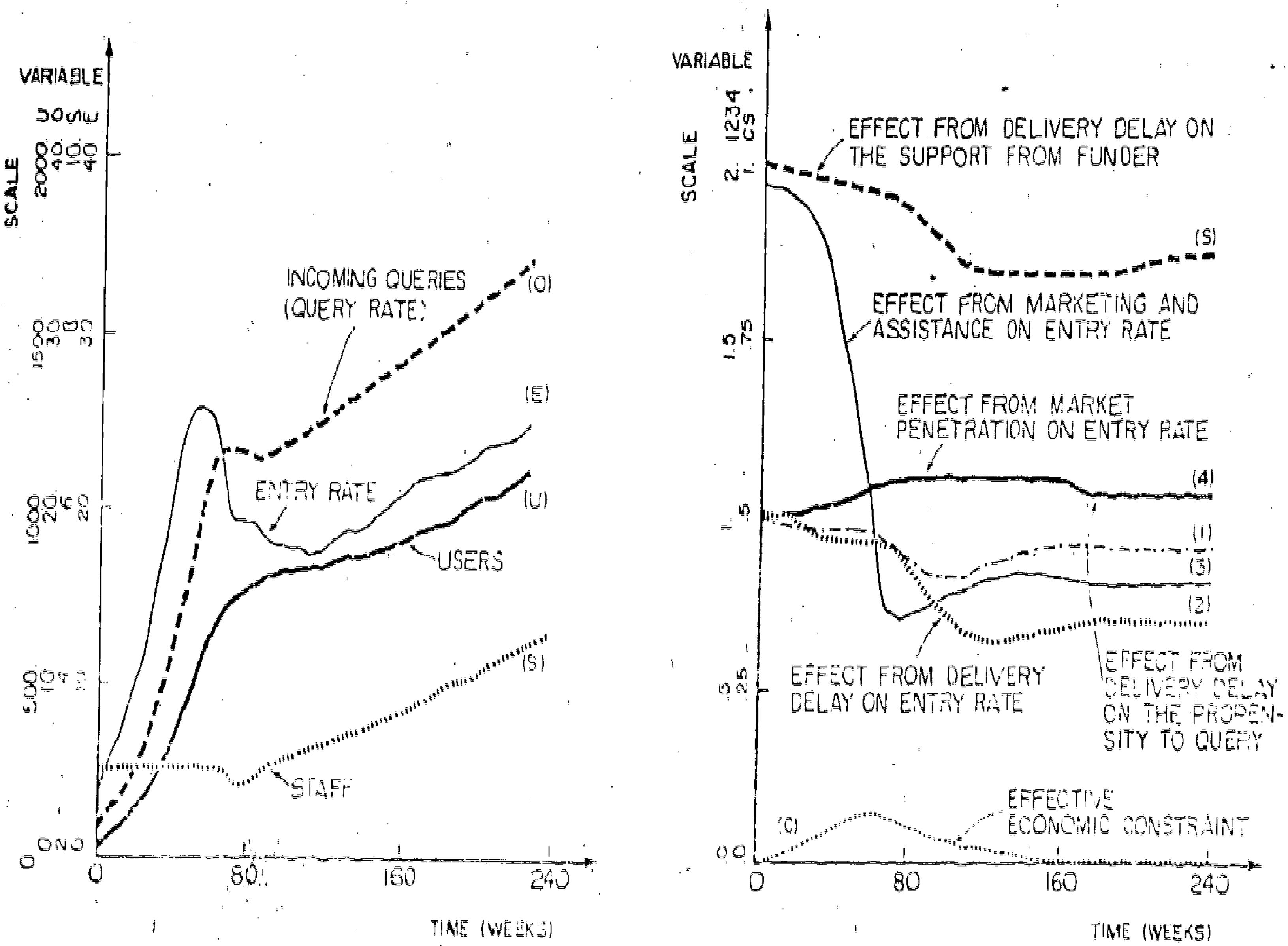


Figure 6
Results from simulation with ISS2

Results from computer simulation with ISS2 are given in Figure 6. The behavior of the simulation model is realistic in both qualitative and quantitative terms, as verified by interviews and literature sources (Brown, 1977; Wanger et al., 1976; Benefeld et al., 1975; Tomberg, 1977-a).

By analyzing the underlying forces, contained in the systems theory, it is possible to explain the behavior. One explanation is given in Chapter two (pp. 76-84) and in ECISS (p.181) the explanation is given in more general terms. This latter explanation is made on the basis of a more aggregated loop-diagram (Figure 7) and reads:

> Loop 1 is typical for business and service activities; as business volume goes up, expansion is needed and more resources acquired which makes it possible to handle more business. Loop 2 is the congestion loop. As business volume goes up, the fact that queues develop makes the service less attractive and discourages business. ISSs easily become congested, and at least part of the reason for this is a focus on search requests instead of users: capacity planning is done on the basis of "how many questions can we answer? rather than "how many users can we serve?" The point is that accepting a user should be a long term commitment. Until it is seen as such, we can say that too many users are admitted to the service. This, of course, would not be the case if the sponsor would expand the resources for the ISS quickly enough. However, the typical sponsor wants to be sure of an established need for more resources before he grants expansion (willing risk capital is indeed rare), but by the time the need is established, there is already congestion, which also hinders expansion (loop 3). One reason for the latter effect is that the "excess" number of users reduces the throughput, since the ISS staff is forced to spend time on user assistance, which will lower the revenue/cost ratio and activate economic concern on the part of the sponsor.

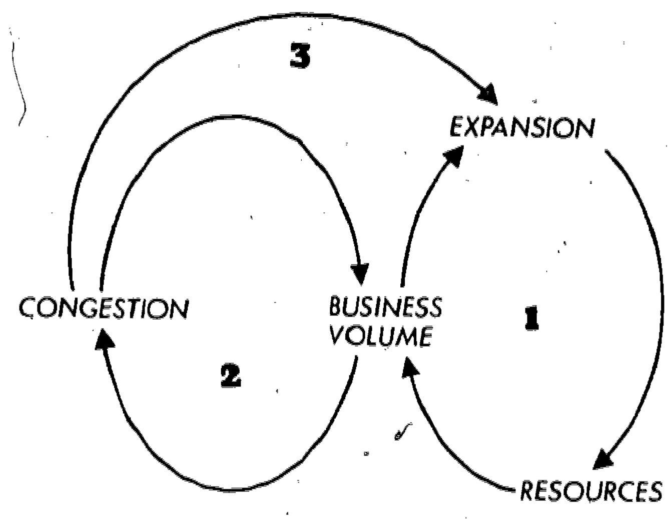


Figure 7
Structure of ISS2

An analysis of managerial decision making for ISSs is also given (see pp. 84-91). The conclusions and recommendations from this analysis can be summarized:

- Management focus has been on queries instead of users which has had a misleading effect on planning and investment activitied.
- The importance of the price-mechanism has been overestimated and not understood (a conclusion from the literature studies).
- The possibility to expand, in staff, is hindered by the doublebind of queues which are needed to justify expansion and at the same time discourage users.
- Marketing and assistance can have a negative effect on sales; there is a possible "marketing trap" (which is partly a function of the first point: focus on queries and not users).

IV. IMPLICATIONS FOR THE AGGREGATE INFORMATION SEARCH MARKET

In general growth forecasts for the computer-based information services market have been optimistic:

> "The market for these services (bibliographic and document retrieval systems) is expected to grow to a substantial size some time during the coming decade. This market is presently in a period of rapid growth of the order of 30 percent per year. Such service is presently limited to libraries, but the price is already within a range acceptable to many business and professional users, and an even more rapid growth can be expected when this type of service is made available as a part of a package of services tailored to the needs of the individual user who is not a computer professional." (Program in Information Technology and Telecommunications, 1976, p. 16)

One of the results of our analysis of ISS growth (see the previous section) was the identification of several common misconceptions regarding the operation of ISS's. Briefly described these misconceptions are:

- The length of time a typical ISS has been operational is often overestimated. The consequence of this could be that an initial, transcient, growth might be believed to be a mature, stable, growth.
- The number of searches a person can perform in a week, say, is often overestimated.
- Too much reliance has been put on pricing policies as a control instrument for the growth development of ISS's.
- In most ISS models the representation of the users and their influence is too simplified and, in general, too little emphasis has been put on factors outside the ISS itself.

In ECSISS (reprinted in Chapter four) the consequences of these misconceptions are discussed. It is claimed that the model ISS2 is a relevant model of the growth development of an ISS, and the implication is that since a typical ISS will experience a stagnation, there are reasons to question the optimistic forecasts. Since the growth of the aggregate information search market is dependent on other developments, e. g. in the publishing industry and the integration of ISS´s and other information utilities, a stagnation in the market is judged not to be inevitable but likely.

V. GENERAL CONCLUSIONS FROM THE STUDY

By applying the system dynamics methodology to the study of information search services it has been possible to attain:

- A deeper understanding of the mechanisms that determine the growth behavior of ISS´s.
- An analysis of managerial decision making that gives recommendations for policy decisions.
- A basis for assessing the development of the aggregate information search market.

We find these to be good indicators of the applicability and suitability of system dynamics for the study of problems relating to the growth development of ISS´s.

Like many other research activities this study points to other areas where more research is needed. The analysis in Chapter four indicates that the investment function is of great importance for an ISS when regarded as an economic system. Considering that there are indications not only of a temporary stagnation, which we have shown, but of a possible decline, which is shown by Tomberg (1977-a) - see Figure 8 - a thorough study of the economics of the whole market is warranted.

To make this possible more research is needed in "information economics", which is defined by McDonough (1963):

> "Information economics is the study of the allocation of certain scarce resources of an organization to achieve the best decisions for that organization. In particular, information economics concentrates on the allocation of resources for the storage of knowledge, for the obtaining of information through data processing, and for the effective utilization of both stored knowledge and processed information by individuals in the firm."

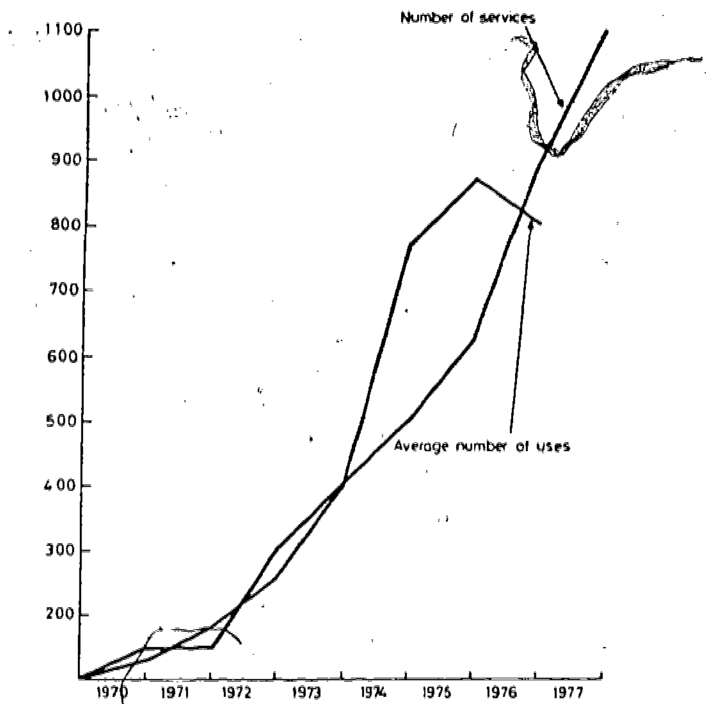


Figure 8

The number of European bibliographic on-line services and average number of users since 1969 (=100) (from Tomberg, 1977-a).

As the present study has illustrated an ISS is best studied as one part of an integrated ISS/user/funder system, and without an "information economic" coupling to the users´ organization any real understanding of the economics of an ISS is not possible.

At present the options available for the ISS management are relatively few with regard to service offerings, as was discussed in Chapter two, but this situation is changing. New service features are being introduced which will make it possible for the ISS´s to offer diversified service. For the managerial decisions involved in the selection of "service mix" a more thorough knowledge of the users´ preferences and behavior is needed.

Finally, it is to be hoped that this study of the dynamics of ISS's can give some motivation for ISS managers to spend resources on collecting more detailed statistics about the ISS operations and user behavior. The theory presented here is general in nature and must be complemented with specific information about the user population of a particular ISS to make it possible to judge the applicability of the theory to the specific case which can guide the managerial decision making for the ISS.

CHAPTER TWO
GROWTH DYNAMICS OF INFORMATION SEARCH SERVICES

I. INTRODUCTION

Information search service of the kind described in Chapter one were, and still are, considered an efficient solution to the problem of access to the scientific literature. Usually the ISS's experienced growth in the number of users. Sometimes this growth was quite dramatic. However, by looking at the situation a bit closer it was possible to find reasons to believe that the rapid growth might not prevail.

For example, preliminary analysis of unpublished statistics showed that at the NASIC/MIT service growth was slowing down. This observation was later confirmed in the quarterly reports. The development of the number of searches per quarter at NASIC/MIT is given in Figure 1.

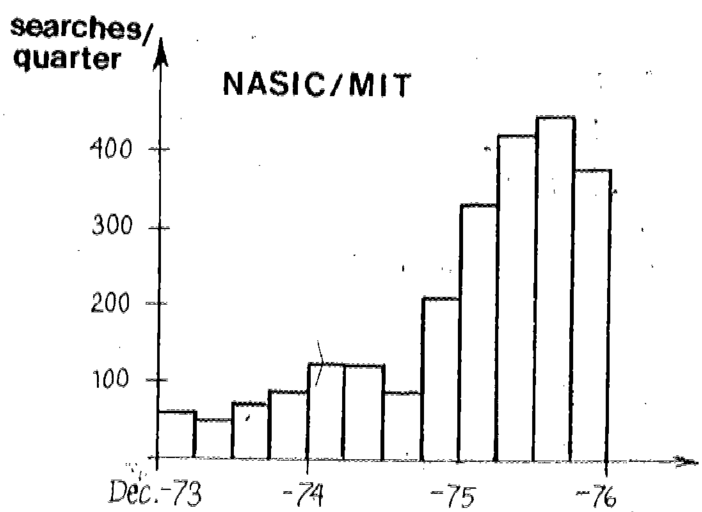


Figure 1

The number of searches/quarter at NASIC/MIT.

We see that with the exception of the summer of 1974 the growth during the first two years follows what looks like an exponential path, and then show relatively little variation for a period of a year and a half, after which growth seems to resume.

By inspecting the statistics from the Royal Institute of Technology IDC we can see a similar development although not as clearly. The development of the number of search requests per quarter at RITL-IDC is shown in Figure 2. The summer of 1973 this service was offered free of charge within the institute which accounts for the high number of search requests during the fourth and fifth quarter. If we discount for this we can see that the growth during the first two years is almost exponential.

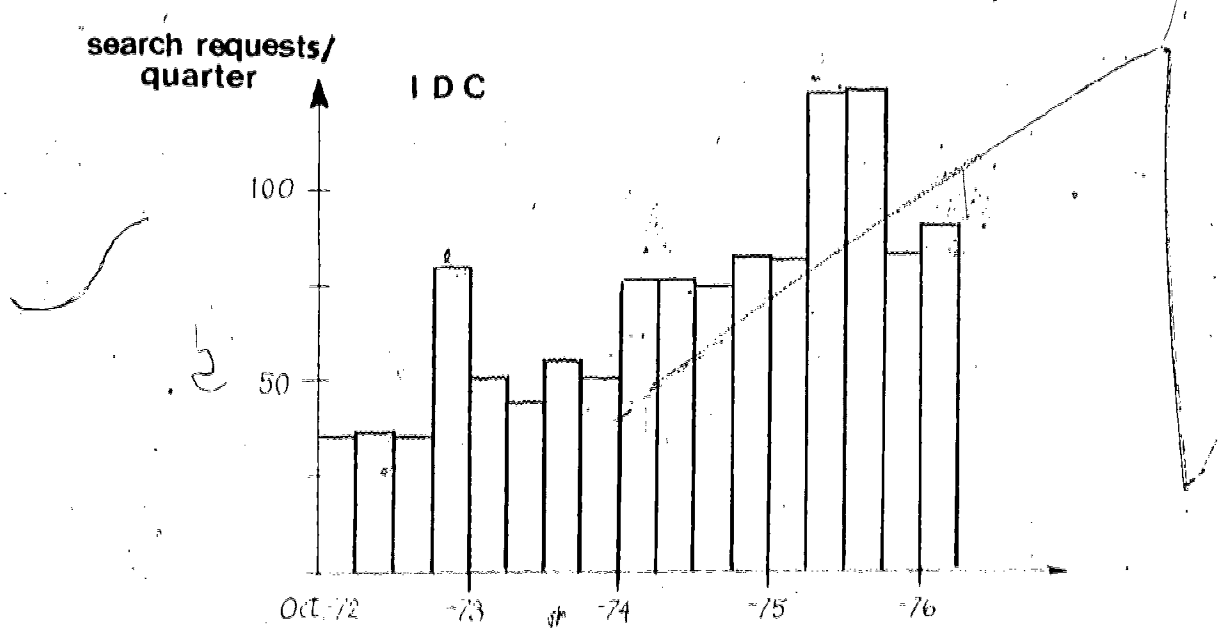


Figure 2

The number of search requests per quarter at RITL-IDC.

The starting level seems a bit high but this can be explained by the fact that the on-line search service benefited from being associated with an established SDI-service; there was already a market for bibliographic information and there were established channels for the marketing. From February 1976 the growth development looks very different from that at NASIC/MIT. The reason for this is that the operations at RITL-IDC changed character in a fundamental way: a communications node was installed which enabled users who had access to dial-up terminals to search directly from these terminals and not to have to go through the RITL-IDC service. This accounts for the sharp drop in the number of search requests for the last two quarters in Figure 2. Much of the increase during the first quarters of 1976 can be attributed to the marketing activities related to the introduction of the node. After this change, however, the RITL-IDC service cannot be considered a typical ISS as we have defined it in this study.

A third indication of growth problems is given by Brown (1977) in an account of the experiences at the National Bureau of Standars Library. The library serves a staff of about 3 000 people, less than half of whom are highly trained scientists and technologists. The library set up an ISS in 1974.

> "In the second year of searching.., the number of first-time users decreased and fell finally for two months to zero. It was not known whether this meant that a saturation point had been reached of new users in the organization, or whether publicity, which had dropped off during a period of staff shortages, was indeed the only effective means of attracting the novice. It was hard to believe that all potential customers had been reached, since the users were only a small percentage of the organization staff" (p. 156)

II. PROBLEM STATEMENT

The problem addressed in this study is that of irregular growth of ISS's, i.e. after a period of initial growth the number of users of an ISS typically levels off dramatically (see Figure 3) even though the potential market is not nearly penetrated. This premature decline in growth contributes to management uncertainty regarding the continuation of the service. The large initial investment to establish an ISS serves to heighten concern over an early growth curtailment.

The difficulty in maintaining growth until the target market is penetrated, or until an economically self-sustaining level of operation is reached, can be a strong inhibiting force on the growth of the number of surviving ISS's. Since overoptimistic forecasts for growth are common, overexpectations by the funder occur, and the problem is often referred to as that of "insufficient growth".

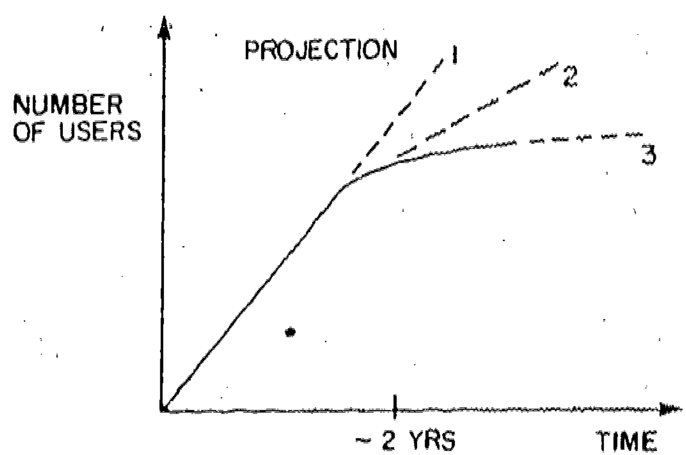


Figure 3

Typical development of the number of users of an ISS.

If the current mental pictures and beliefs prevail and are used as a basis for forecasts and expectations the fate of the on-line based ISS´s can be the same as that of the SDI operations of the mid-1960´s, i.e. after a period of success, with growth in both the number of services and the number of users per center, use deteriorated to a level below that warranting continuation. The number of SDI operations declined rapidly, and today the SDI function is carried out by a few large centers or is offered as an option by the larger ISS´s.

Overexpectations occur and reoccur because of a lack of knowledge of underlying factors. The established knowledge of user behavior and market reactions is insufficient for guiding the ISS managers. This claim is substantiated by the following quote:

> "...totally inadequate conceptions concerning STI (Scientific and Technical Information) users are guiding the thinking of many STI/SS (Scientific and Technical Information Systems and Services) designers and managers. Unless and until research is done that reshapes current "mental pictures" of who can or might use STI/SS´s, hopes for seeing major improvements in the delivery and utilization of such systems and services are bound to be frustrated". (Freeman and Rubenstein, 1974, p. 9)

The purpose of this paper is to present an analysis of causes for the growth behavior of ISSs. It offers an explanation of the observed growth behavior of ISS´s. It offers an explanation of the observed growth development and can serve as a basis for further understanding needed for effective management decision making. The analysis is based on results from computer simulations with a model of a hypothetical ISS.

III. BOUNDARY FOR THE STUDY

Depending on the objective of a systems study its boundary can be different from what is traditionally held to be the system boundary. For a study of the growth of an ISS the appropriate boundary must include, in addition to the ISS itself, both the funder and the users since their decisions and actions have a direct effect on the ISS (Baker and Nance, 1968, 1969, and 1970).

The structure of an information search service has previously been discussed and related to the overall activity of user access to the scientific literature (see p. 18).

The performance of an ISS is evaluated from different viewpoints: management evaluates the goal fulfillment, the funder, the users, and the potential users evaluate the service in some utility terms. All these evaluations lead to decisions and actions that affect the future operations of the ISS.

The management decisions.

Management tries to keep the delivery delay for the service, the response time, at an acceptable level by allocating staff effort to the "production" function, i.e. performing the information searches. The resources not needed to achieve the delivery delay goal are employed in user assistance and marketing. There is a constraint for the allocation policy since a certain minimum effort is required for user assistance. Part of this minimum is spent on administrative work.

A less obvious way for management to increase the productive capacity is to decrease the staff time spent on each query. Such changes can only be made slowly since they involve a learning process by the staff and an adjustment time for the users. The time spent per query has a strong effect on the quality of the service and is a high-level policy variable. In the study we assume that the quality goal is not changed.

The users and their decisions.

The definition of a "user" of an ISS is uncertain when there is no formal contract, like a subscription, on which to base the definition (Marron, 1969). In this study a user is defined as a person who decides to use the ISS, and he remains a user for a "normal user time", unless the effect of delivery delays will make him terminate his interactions sooner, i.e. exercise the exit option discussed on p. 25.

The users submit queries according to their average propensity to query. This propensity, however, is influenced by the experienced delivery delay: if this is long then the propensity to query will be lower.

The potential users.

The potential users decide to become users on the basis of their perception of the value of the service, measured by perceived delivery delay, and the intensity of the marketing effort+. The entry rate is also

+) the importance of these two service characteristics is discussed in (Llewellen and Kaminecki, 1975) and (Berk, 1974) respectively.

subject to influence from the proportion of actual users to potential users: the word-of-mouth effect, which has a positive influence on awareness and entry rate, grows at first with the number of users but saturates when the proportion of users is high. There is also a general saturation effect which makes it more difficult to attract and recruit users as the market penetration approaches 100 per cent.

The funder and his decision.

The funder's assessment of the ISS operations consists of both a critical and a supportive aspect. On the one hand the ISS must prove its worth in the marketplace, and the criteria used for the critical evaluation are usually economic or some measure of market penetration, i.e. how successful the service is in terms of growth in queries or users+. The critical component will lead to a reduction of support if the growth is not sufficient compared to the funder's expectation.

The supportive component rests on the realization that low performance in terms of growth can be the result of too little resources. ISS's typically have procedures for evaluative feedback from users, which enables them to respond with "voice" in response to a decline in the service quality (see p. 26). If the funder is committed, an expressed low user satisfaction might lead to an increase in the funder's willingness to support the ISS. However, this commitment could not continue indefinitely; thus if user satisfaction does not go up

+) Ekonomic considerations are becoming increasingly important as discussed in (Schwarz, 1976 and DeGennaro, 1975).

in a reasonable period of time, the funder is forced to the conclusion that the users are finding other forms of service.

IV. SYSTEM DESCRIPTION

Behavior is the aggregate of system activity, which includes decision making and actions. Actions lead to changes in the system. When something is done the outcome also changes future doings either because of physical changes in the system or because of psychological changes, i.e. learning. Actions are prompted by decisions. Decisions are influenced by the state of the system which, in turn, is affected by actions. In systems with human decision makers it is always important to account for the possibility that the perceived state of the system can be different from the actual, and to realize that it is the former that is influencing the decision-making. Thus system activity can be described in terms of feedback loops, which are closed paths representing the effects of a decision on the system and on future decisions via information feedback.

A decision can be influenced by very many information sources but to include them all in a system description demands a level of detail that inhibits perception and insight. Thus system description variables must be selected carefully. It is easy to construe a thousand reasons for a decision, but the "good reasons" are few; the set of variables chosen to describe the state of the system must be able to represent all the "good reasons" for the decisions in the system. A study of an information search service must include the number of users and the number of queries as variables describing the state of the system, and a study of the growth of an ISS must include the productive resource staff. In subsequent sections the feedback loops affecting these variables are described. The system loops are numbered in one sequence and are prefixed by the initial of the variable on which they exert the primary influence.

Loops affecting the number of users.

The feedback loops affecting the number of users are given in Figure 4.

Loop U1 represents the natural tendency for growth in the number of users. There is an intrinsic need for an ISS+ and the most important factor affecting the growth is awareness of the service which is, in turn, largely determined by word-of-mouth although the marketing effort by the ISS might prompt the actual decision to become a user (Benenfeld et al., 1975, p. 1-4). Thus until the ISS has reached its service capacity the number of users could grow at an increasing rate.

Loops U4 and U2 are loops that inhibit the growth in users. Loop U4 is the market saturation effect, which represents the increasing difficulty in recruiting new users within a saturated population of potential users. Loop U2 portrays a negative effect from delivery delay on entries. As more users enter the number of queries increases which lengthens the delivery delay which, in turn reduces the number of future entries.

+) That this is true also outside research oriented academic communities is shown in (Ahlgren, 1975).

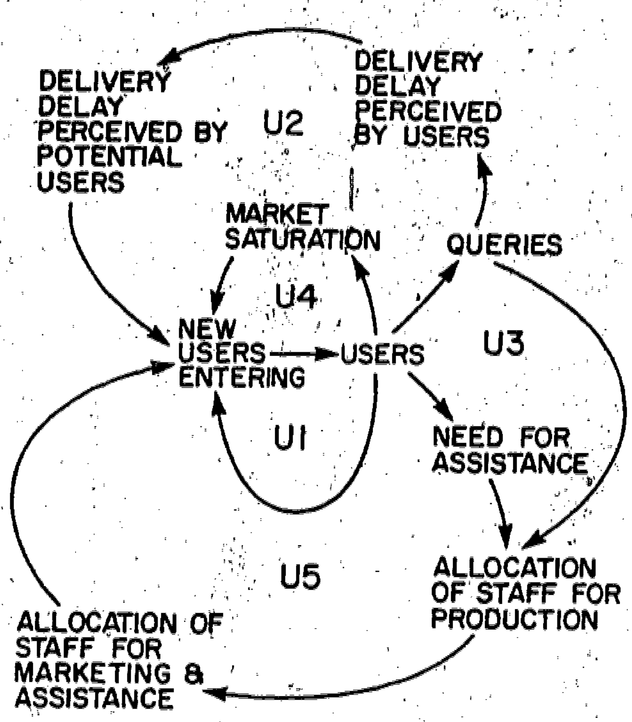


Figure 4
Feedback loops affecting the number of users.

Loop U3 shows another factor inhibiting the number of entries. As the number of queries increases, more staff is needed for production, i.e. increased searching decreases staff resources available for marketing and user assistance. This negative effect is counteracted by the effect of loop U5 which is to make it more difficult to allocate staff for production as the need for assistance increases.

Feedback loops affecting the number of queries.

In Figure 5 the feedback loops affecting the number of queries are shown together with the previously discussed loops. Loop Q6 represents the effect of user perception of good service, i.e. short delivery delay effects an increase in user propensity to query. Conversely a decrease in the propensity to query is the reaction as delivery delay increases. A build up of query backlog lengthens the delivery delay causing a negative effect on the number of incoming queries. This effect is amplified by loop U2 which gives a reduction in the number of users, and hence queries, when delivery delay is long.

The managerial policy for resource allocation is represented in loop Q7: when query backlog rises the allocation of staff to production is increased which increases the answer rate and reduces the backlog. The delivery delay is shortened by both the increase in answer rate and the reduction in query backlog. Loop Q8 shows a dysfunctional effect of the resource allocation decisions, in terms of control of the query backlog. As the answer rate increases the delivery delay decreases which eventually stimulates an increase in query submission and causes potential users to become users.

Feedback loops affecting the number of staff

Figure 5 gives all the loops necessary to analyze the behavior of an ISS under constant staffing. For some studies this would be adequate since an ISS sometimes is set up as a research project or experimental activity

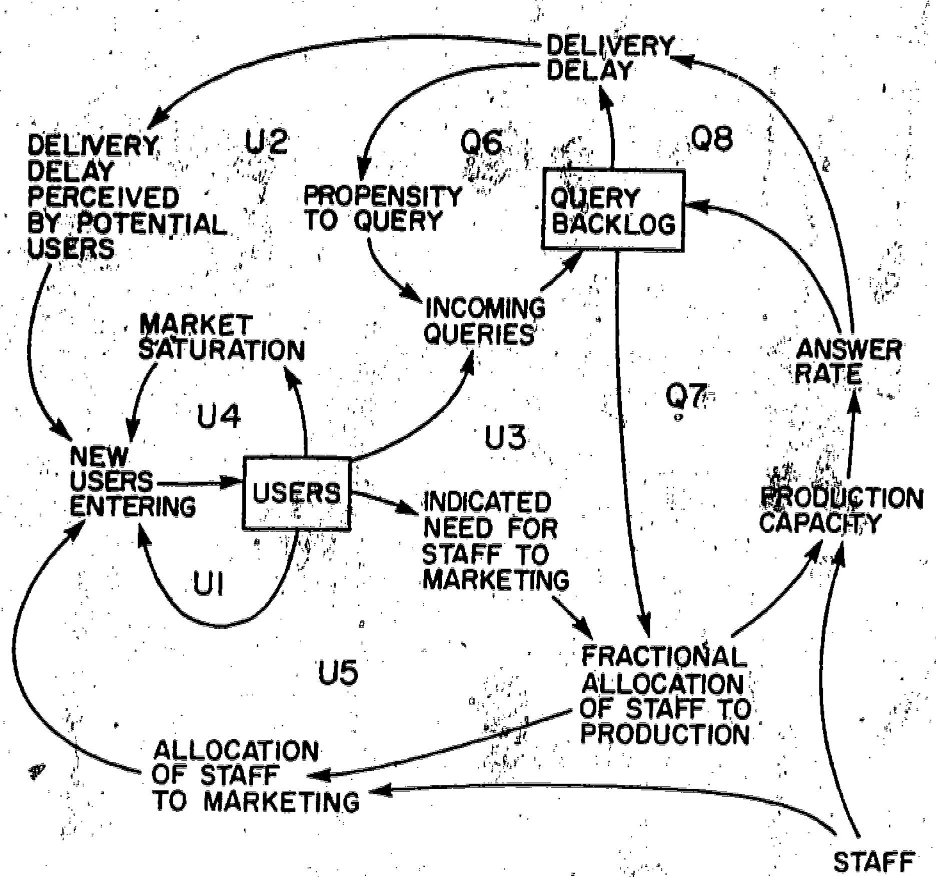


Figure 5
ck loops affecting the
of users and queries.

with a fixed budget. The most common setting for an ISS, however, is to be part of a larger organization, such as a library, and subject to budgetary concerns. Therefore feedback loops affecting the number of staff are necessary. These are shown in Figure 6.

Loop S9 represents the compensation for leaving staff. As staff increases so will the number of staff leaving, assuming that the average time to stay is not changed.

This will lead to an increase in the number of desired and eventual hires.

The expansion of the ISS in terms of staff is shown in loop S10. In the typical organizational setting for an ISS justification for expansion is normally based on a demonstrated "need" such as a high backlog of queries or long delivery delay.

One of the two primary constraints on expansion is represented by the funder's willingness to support the ISS. If delivery delays are long for a sustained period of time the funder's willingness to support must decline since solicited evaluations of the service are low. The second constraint is economical and is represented by loops S12 and S13. Establishment of an ISS requires a relatively large investment, and operation has high and visible marginal costs, such as search fees to the information wholesalers and telecommunication costs. It is therefore common to require the ISS to recover some of these costs (Wanger <u>et al.</u>, 1976, p.153). Rarely is the recovery of the initial investment expected, and the economic constraint contains only variable costs - staff salaries and search costs. The funder expects a certain volume of searches per staff member, and this ratio is determining the economic constraint.

Loop S12 is a positive loop depicting the influence of an increase in staff: shorter delivery delay, more incoming queries, and an improved queries per staff ratio, which reduces the economic constraint on hires. Loop S13 is a negative loop since an increase in staff leads to lower queries per staff ratio and a negative influence on hires.

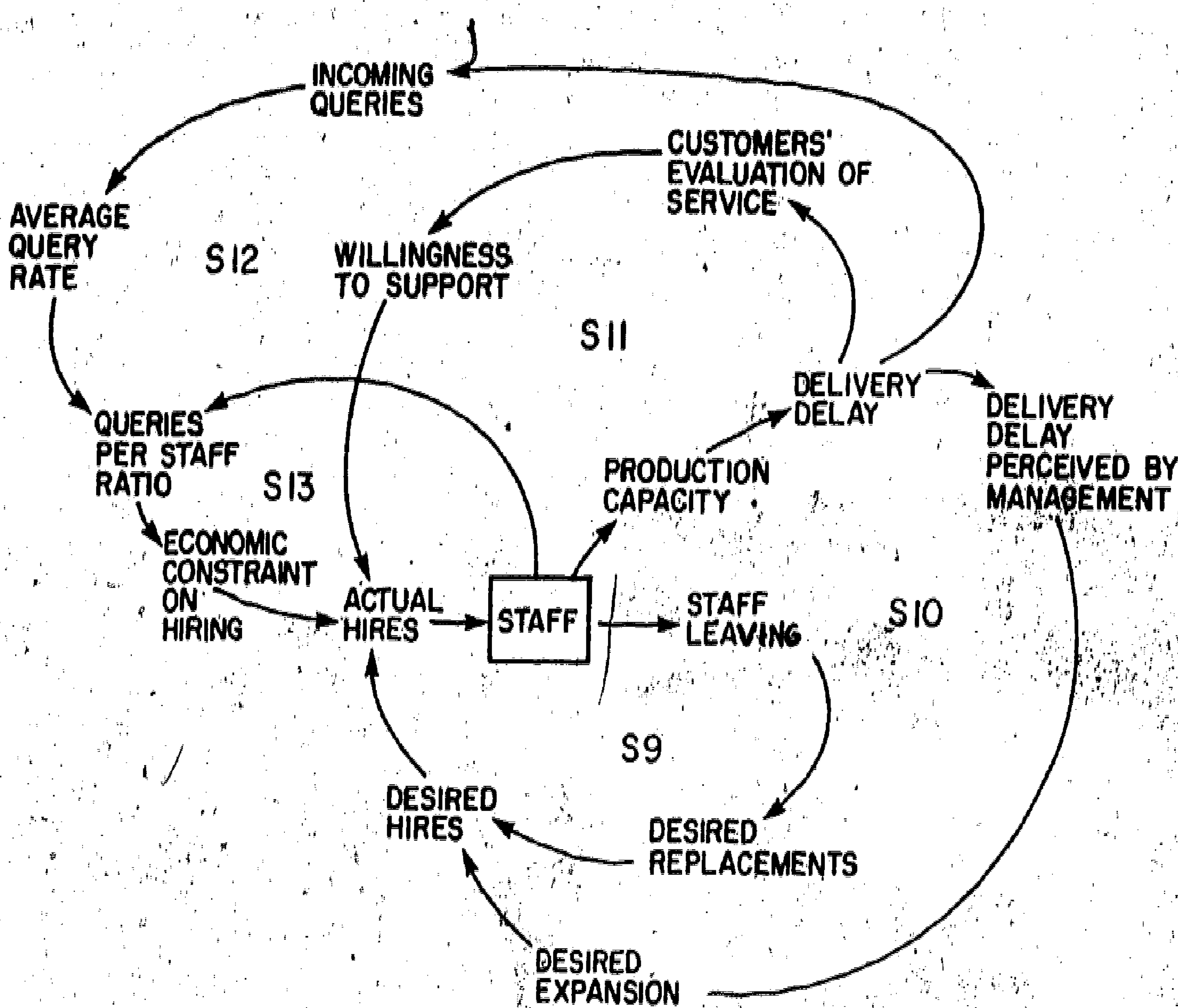


Figure 6.

Feedback loops affecting the number of staff.

V. THE SIMULATION MODEL AND BEHAVIOR OF AN ISS

The simulation model is a system dynamics model written in the DYNAMO simulation language see (Forrester, 1968) and (Pugh, 1973) for a description. Conceptually a system dynamics model is a set of differential equations describing the continous changes in a system. As implemented on a digital computer the model equations are formally a set of first order difference equations. A further discussion about the mathematical representation is given in Chapter three as part of the detailed model description.

Formulating the model means writing the model equations on basis of the causal analysis and the causal loop diagrams. Normally the equations are more detailed than the diagrams so the question of selecting variables must be addressed again.

The choice of which variables should be included in a system dynamics model depends on the purpose of the study, or the "point of view", and on the level of aggregation. The latter is often a consequence of the former but can also be influenced by available resources. The choice of variables should not be based on what data is available; a system dynamics study can work the other way - point out what data is needed to make the study relevant.

The boundary for the studied system is both crucial and difficult to determine. There is danger of omitting important variables, which typically results in neglected representation of influences that have a controlling effect on one or more of the system variables, i.e. negative feedback loops. Such omissions could be the consequence of the modeler's "methodological bias" (Andersen, 1977, p. 41 ff.) to think in "loops". All relevant relationships between variables must be identified before the decision about inclusion/exclusion can be made. One way of reducing the danger of faulty exclusions is to apply precedence analysis (Langefors, 1966) when constructing the model or, if this is not done, for verification of crucial parts of the model. This analysis is in itself static and for each variable one poses the question "On what does the value of this variable depend?", i.e, one identifies all the information precedents needed to compute the value. When this is done it is possible to consider aggregations and exclusions.

The process will be illustrated with the formulation of the representation of "quality" and connected parts of the model ISS2 as example.

As a starting point for the discussion we illustrate, in Figure 7, how decisions, actions, and information feedback interact in a loop structure (see p. 98 for a description of the symbols used). The decision controls the action stream. Action changes the state or condition of the system, here called the level of the system (cf. p. 95). The actual level of the system affects the information about the level, which is the basis for the decision.

A decision is typically influenced by a number of information inputs. If every possible information input were to be included in the model perceivability would be lost. If, on the other hand, important variables are not included in the model it cannot adequately represent the dynamic behavior of the system.

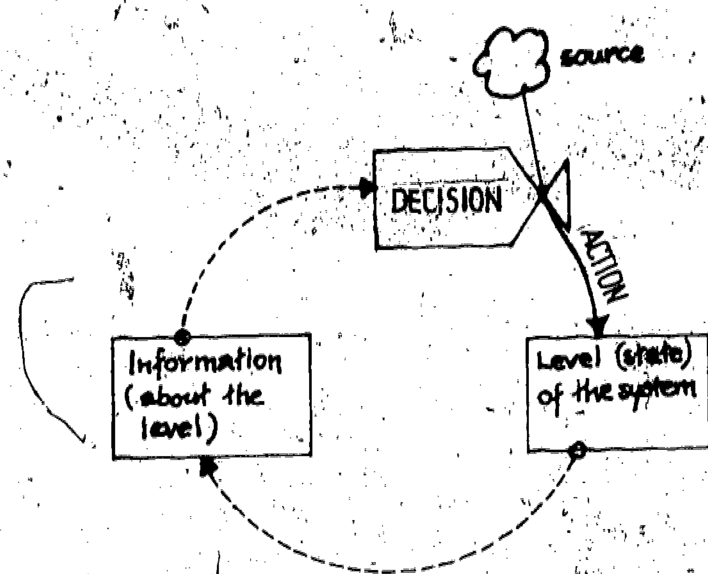


Figure 7

The structure of a feedback loop (from Forrester, 1968, p. 1-4).

The criterion for the system boundary is given by Forrester (1968, p. 4-2):

> "In concept a feedback system is a closed system. Its dynamic behavior arises whitin its internal structure. Any interaction which is essential to the behavior mode being investigated must be included inside the system boundary".

In other words, a variable cannot be excluded if it affects a decision which in turn has a significant effect on other model variables given the purpose of the study.

As an example consider the precedents to "information base"; they can be listed:

- availablility of data bases
- competitive situation (between wholesalers)
- cost of storage
- capacity of the system installation

None of these have precedents within the ISS/user/funder system being studied. A possibility would be that the users influenced the acquisitions but the information search market is essentially supply driven. The cc t for building a data base is very high and the motivation to take down a data base is low since "the number of databases" is used as a marketing argument.

Similarly "formats and channels" are determined by factors outside the ISS/user/funder system.

"Other components" are by definition outside the system boundary.

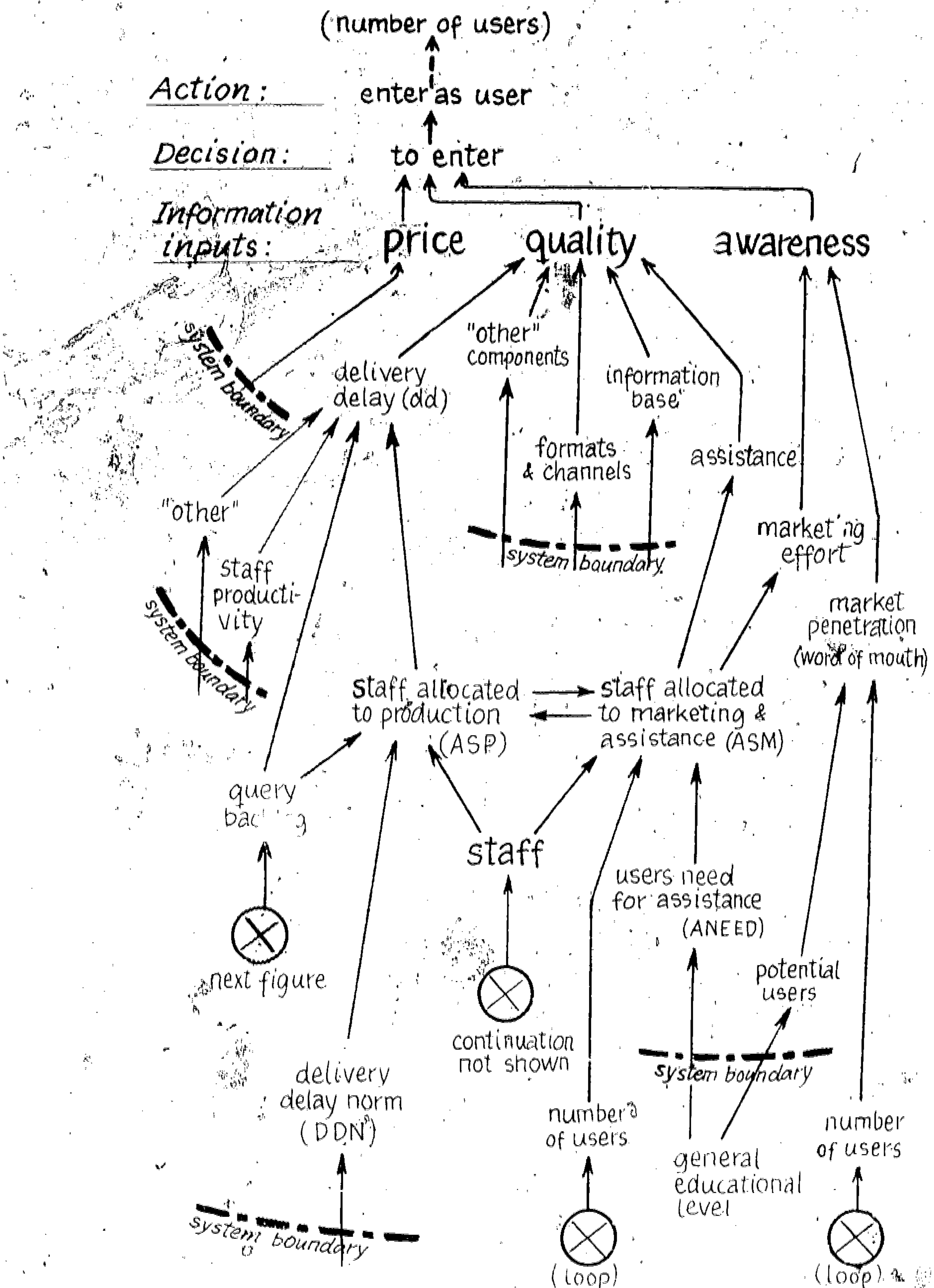
Price could be excluded from the model on similar grounds, since in practice the ISS pass on the costs from the wholesaler, but this would not be quite adequate since various pricing schemes are practiced and the generality of the model would not have been demonstrated without the given analysis of the effect of price changes (see p. 21): it had to be shown that the users´ decision are not influenced significantly by price.

Quality, as has already been discussed (see p. 23), is one of the determinants of sales, i.e. it is one of the inputs to the decision of a potential user to became a user as is shown in Figure 8. The modeler´s exclusion decision can now be illustrated as a question of crossing the system boundary.

In Figure 9 "quality" is shown to be a precedent to "users' propensity to query". Here, by definition, the precedents to "quality" with the exception of "delivery delay" are outside the system boundary. It is the assumption of this study that new users and return users behave differently, i.e. act on different sets of information inputs. The propensity to query is a measure of how often a user will return to the ISS. Since he is already familiar with the service, marketing is assumed not to influence the decision to return.

The representation of these boundary crossings in the system dynamics model is typically done by a constant that represents the influence of factors outside the model on the model variables. When the numerical value of the constant is determined it is important to consider the effects of all the precedents.

The modeler's decision whether to combine two system components, be they variables or constants, can be facilitated by making a precedence matrix. In Figure 10 the graph of Figure 8 is represented in this way. From the matrix it can be seen that "assistance" and "marketing" have the same precedence set, the amount of staff not allocated to production (ASM), but since they have different succedents (rows 9 and 10) it is not without problem to combine the two. However, since it is in practice difficult to draw the line between the assistance and the marketing functions it is natural to think in terms of a combined function, and in this case a matrix like the one in Figure 9 helps to keep track of the original precedence relationships



(number of users)
Action:
enter as user
Decision:
to enter
Information inputs:
price
quality
awareness
system boundary
delivery delay (dd)
"other" components
information base
formats & channels
assistance
system boundary
"other"
staff productivity
system boundary
marketing effort
market penetration (word of mouth)
staff allocated to production (ASP)
staff allocated to marketing & assistance (ASM)
query backlog
staff
users need for assistance (ANEED)
next figure
continuation not shown
potential users
system boundary
delivery delay norm (DDN)
number of users
general educational level
number of users
system boundary
(loop)
(loop)

Figure 8

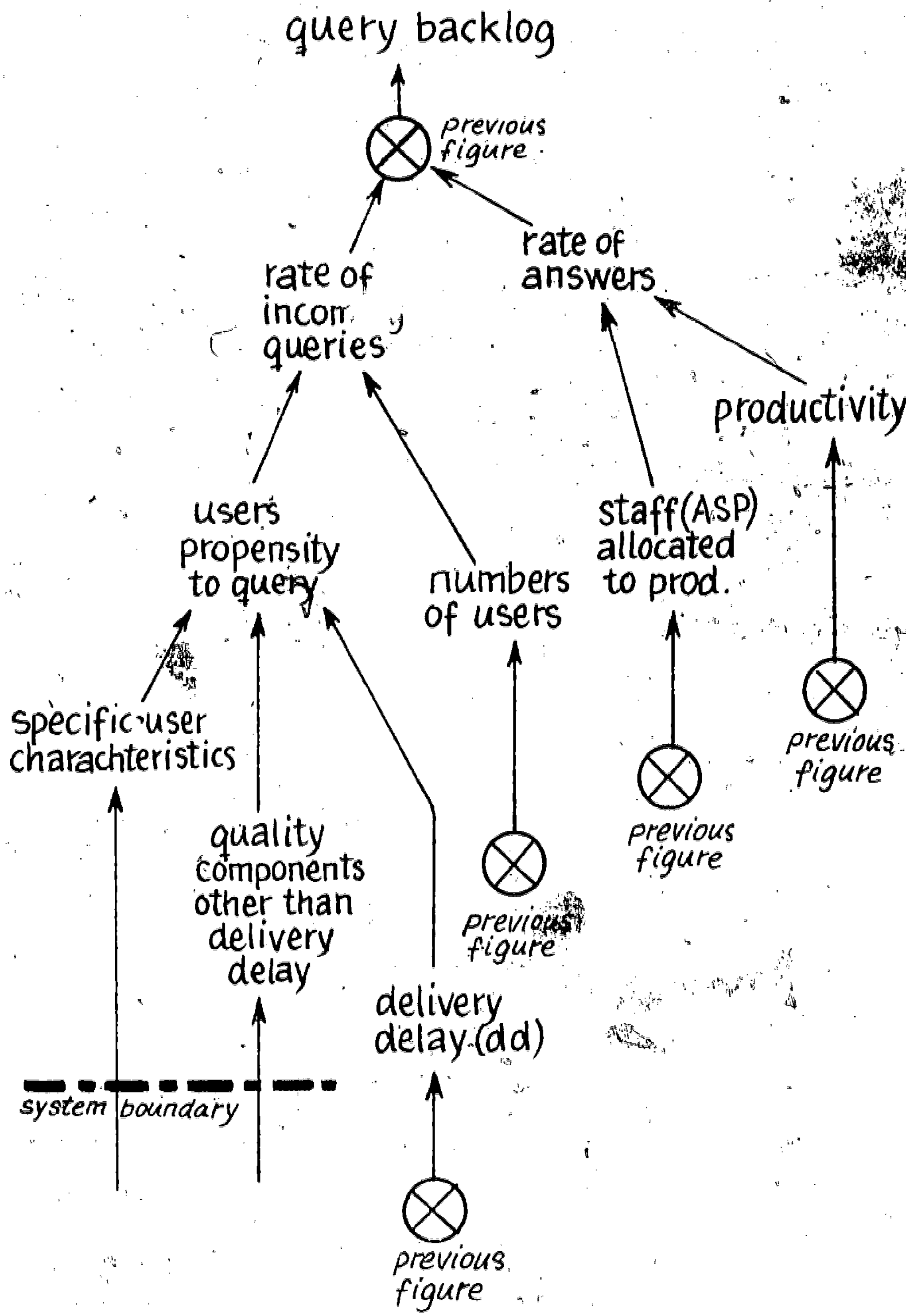

query backlog
previous figure
rate of incom queries
rate of answers
productivity
users propensity to query
numbers of users
staff(ASP) allocated to prod.
specific user charachteristics
quality components other than delivery delay
delivery delay (dd)
previous figure
previous figure
previous figure
previous figure
system boundary
previous figure

Figure 9

	users (1)	termination rate	entry rate	price	quality (5)	awareness	formats & channels	information base	assistance	marketing (10)	delivery delay	ASP	ASM	market penetration	productivity (15)	DDN	ANEED	potential users	query backlog	staff (20)
(1) users													1	1						
termination rate	1																			
entry rate																				
price			(1)																	
(5) quality			1																	
awareness			1																	
formats & channels					1															
information base					1															
assistance					1															
(10) marketing						1														
delivery delay					1															
ASP											1									
ASM									1	1		1								
market penetration						1														
(15) productivity											1									
DDN												1								
ANEED													1							
potential users											1			1						
query backlog												1								
(20) staff												1	1							
exogenous			(1)		1		1	1			1				1	1	1	1		

(outside Figure 8)

Figure 10

which are important when the interrelationships between system components are quantified.

A precedence matrix also gives an explicit list of all the components left outside the system boundary (row 21).

The numerical values chosen for the parameters of the simulation model ISS2 are representative of an ISS in an academic setting. The quantified model represents a synthesis of information from literature sources augmented by correspondence with, and study visits to operational ISS´s, as presented in Chapter three.

The simulated ISS thus begins with a staff of three persons. The average number of searches per staff is ten per week, and management tries to keep delivery delay at half a week. The potential market for the ISS is 2 000 users, each having a normal information need of almost two searches per year. Figures 11-a and 11-b show the behavior of the system variables resulting from a simulation run of the first 240 weeks of operation.

The simulated ISS grows rapidly in terms of the number of users for the first 60 weeks, and then the typical decline in growth occurs when the number of users is about 800. From then on the growth is significantly slower, but the ISS is satisfying the funder´s economic requirements. Since the delivery delay is maintained near the norm the ISS expands and has a staff of 4.4 at the end of the 240 weeks. The number of users at that time is 1137, which means a market penetration of 57 percent. The ISS receives 35 search requests per week, and the number of new users is 25 per week, which

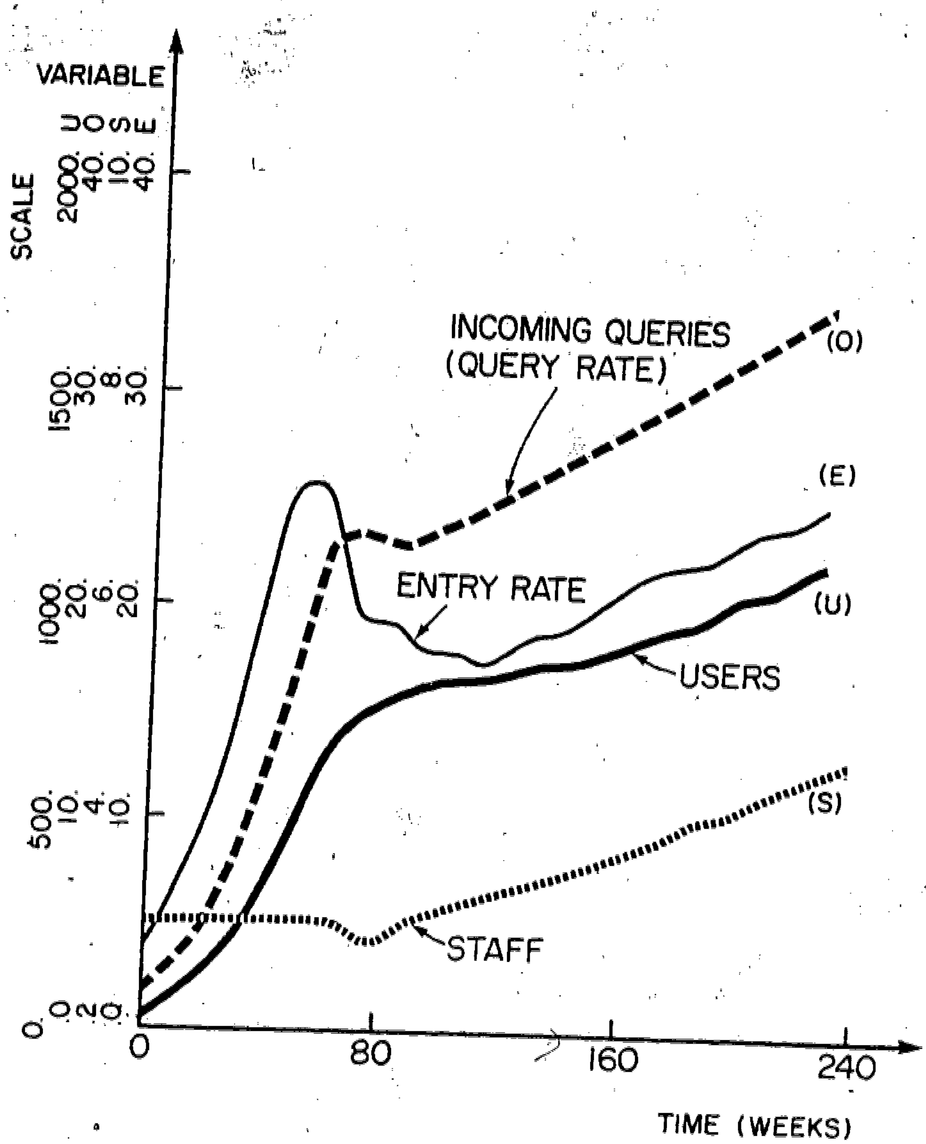


Figure 11-a
Reference run of ISS2 (part I)

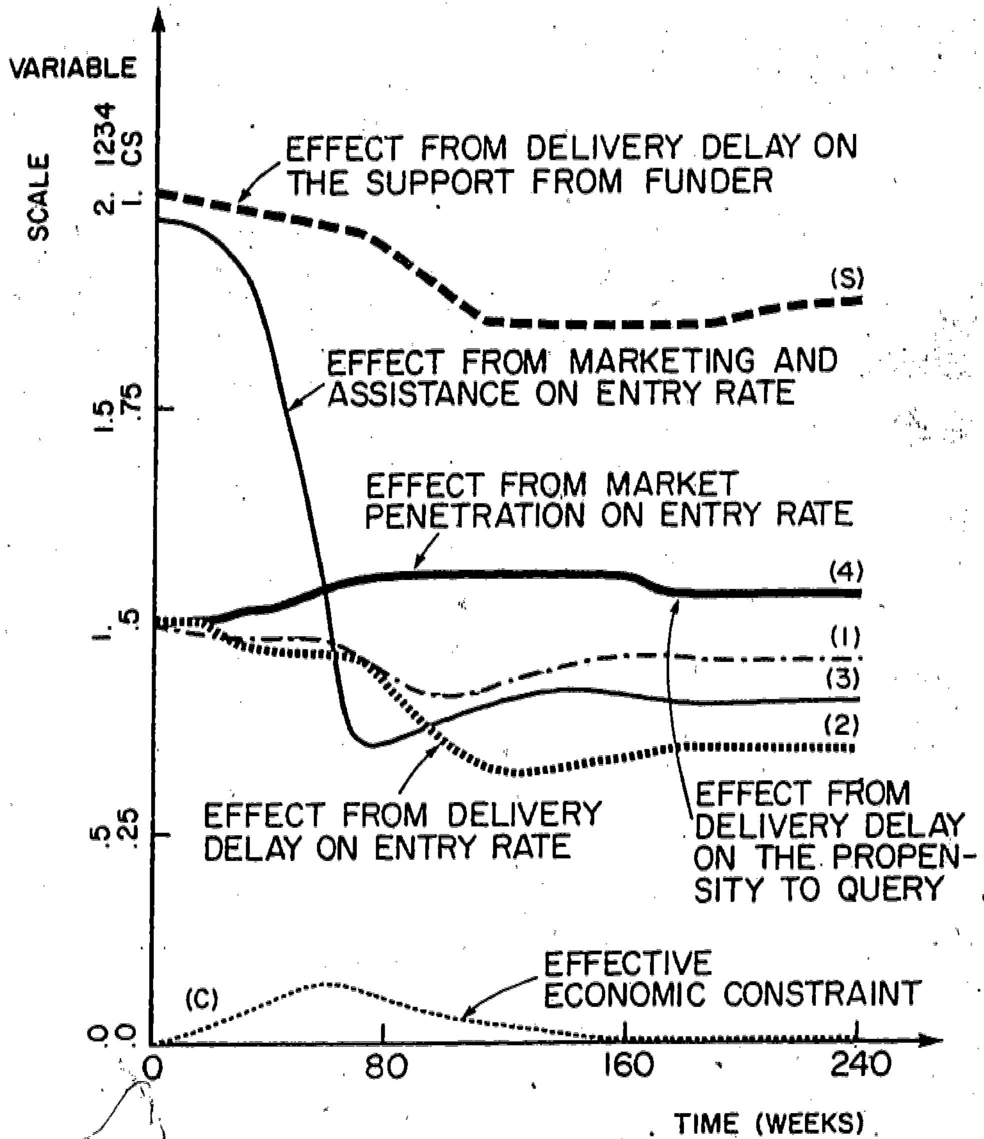


Figure 11-b
Reference run of ISS2 (part II)

means that the percentage of "return users" is 29.

The overall behavior of the model conforms well with the typical development which was given as part of the problem statement (see p. 56). When it comes to comparing the volume of business problems arise due to the lack of standards for statistics which was discussed in Chapter one (see p. 27). There is also a difference between the model and the statistics that are kept: in the model the users are counted when they decide to become users, in the statistics users are not known until they have actually submitted a query to the ISS. In the long run the figures will be comparable, but in short run simulations the model will show a much higher entry rate of users.

Since ISS2 represents a typical service, i.e. is a general model, variations in actual numbers will occur when the results are compared to any particular ISS.

However, the purpose of the present study is not to make predictive statements regarding specific values of system variables. In a situation where measurement noise is a reality, which is the case in the present study, attempts to make point predictions are likely to be unsucessful. The reasons for this is discussed by Forrester (1961, Appendix K) who concludes:

> "If the presence of noise is admitted, we must necessarily come to the conclusion that even the perfect model may not be a useful predictor of the specific future state of the system it represents. This does not keep the model from being a useful predictor of system improvement that will come from design changes". (p. 431)

An assessment of the realism of the simulation results will have to be made in more general terms. For this purpose several performance related and operational measures were listed as part of the simulations runs (see p. 156) and together with the model variables in Figure 4 in Chapter three these measures provide a basis for judging the realism of the simulations results.

Looking at the NASIC/MIT service we can make some comparisons for the first two years. Thereafter this becomes more difficult since the simulations results give an expansion in staff whereas the NASIC/MIT service has had a constant staff.

The total number of searches during the first year of operation was 316 at NASIC/MIT (Benenfeld et al., 1975); the simulated result for ISS2 is 324. The percentage of return users is a bit lower for ISS2, about 20% compared to about 30% for NASIC/MIT, but this is a consequence of the different representation of users mentioned above. Both NASIC/MIT and ISS2 show, however, an increasing percentage for return users (personal communication, August, 1976). For ISS2 this can be seen by inspecting the simulation result (Figure 11-a): growth in incoming queries is, for the second half of the simulation run, higher than the growth in user entries. After about two years the query backlog for ISS2 is about 18; inspection of the NASIC/MIT appointment calendar at the corresponding time gave a value of 10-15. Hjerppe (1975, p. 125) reports a backlog of 10-20 search requests. The annual growth rate for ISS2 at this time is about 30% which is consistent with an estimate from a Stanford study (Program in Information Technology and Telecommunications, 1976, p. 15) when one considers that the average age of operational ISS's at the time was about two years (see Chapter four, p. 178 for a discussion).

Based on an assessment of this kind we find the behavior of the simulation model to be realistic in both qualitative and quantitative terms. By analyzing the underlying forces we can obtain an explanation for the behavior. The following analysis will show that the decline in growth is a direct consequence of market responses to the ISS operations.

The "natural" growth of the ISS (loop U1) is amplified during the first year when the volume of queries is insufficient to conflict with the marketing activities. Users are attracted to the service by relatively intensive marketing, adequate assistance, and delivery delay that is practically on par whith their requirements. As more and more resources are needed for production, a declining effect from marketing and assistance on the entry rate (loop U3) follows.

The reactive character of the allocation policy means that the ISS management only allocates resources to production based on an established need, reflected by an increase in the queries in process (loop Q7). The rapid growth in terms of users leads to increasing difficulties in keeping the delivery delay at the norm. The adverse effects on the existing users' propensity to query are counteracted by an increase in the allocation of staff to production and for the first 60 weeks the propensity to query does not drop much below normal. Afterwards, a substantial decrease in propensity causes a negative effect on the query rate (loop Q6). The effect from the increase in delivery delay on entry rate (loop U2) is slower in developing since the potential users do not have first hand experience with the service and their perceptions develop slowly. Once the potential users have made an assessment of the service, it is diffucult for the ISS to change it. Unsatisfied users naturally are less inclined to pay attention to ISS change. Revising the potential users perception is a slow process.

For the first 60 weeks the awareness of the service is growing and the word-of-mouth effect, or the effect from market penetration, contributes to the increasing rate of growth on users (loop U4). The typical ISS does not experience market saturation effects.

The effect from marketing and assistance on entry rate is decreasing for the first 70 weeks which causes a decrease in the entry rate after about one year [illegible] the relatively good delivery delay sitation and [illegible] high awareness of the service. After week 70 the effect from marketing and assistance increases somewhat, partly due to the recognition of the need for assistance for the growing number of users (loop U5) but also helped by the increasing negative effect from delivery on entry rate. This latter effect reduces the growth in users (loop U2), so that the relative effect of the allocation of staff to marketing and assistance is increasing.

The cause of the overshoot in entry rate and the resulting dramatic decline in the growth of the number of users is the decline in staff capacity available for marketing as a consequence of the necessary allocation of staff for production (searching). The flow of incoming queries remains too strong to enable the ISS to keep delivery delays at the norm - a condition which will have an incremental effect on the decrease in entry rate (loop U2).

The initial growth of the ISS is driven primarily by the relatively high marketing effort during the first year. Low awareness of the ISS is cited as one cause of failure to grow (Carmon, 1973), and other studies support the necessity of marketing activities to achieve growth (Berk, 1974). However, it is important to keep the delivery delay at an acceptable level since it is the principal determinant of service quality. So the problem facing the ISS management is to balance the commitments to the users. Accepting a user means a commitment to spend resources on assistance but also implies a longer term commitment to answer submitted queries. This latter commitment is not always recognized as being long-term but observed behavior of ISS's indicates that the demand for resources for production per user does increase after a few years.

The difficulty in finding an ideal balance, i.e. providing adequate assistance to every user while maintaining the delivery delay goal, is illustrated by these results. Delays of various magnitude dependent on the effects of the ISS operations result in decisions by users and potential users. High user expectations are generated and management has difficulties in responding adequately to the demand for assistance as well as for searching.

The predicament of the ISS management is complicated by the funder's reactions. The different phasing of the users' needs for production and assistance makes it difficult to avoid dissapointment in one respect or the other. If too much emphasis is placed on satisfying the need for assistance, then the delivery delay is longer, discouraging users from entering (loop U2). Eventually, the funder's willingness to support the service (loop S11) is reduced which hinders expansion and retards growth. If the production aspect is neglected, the economic constraint on hiring can become binding (loops S12 and S13).

If too little emphasis is placed on marketing and assistance some users are discouraged from using the service, and since delivery delays are relatively short, no visible justification exists for expanding the service (loop S10). This "no-win" situation is sometimes a reality; i.e. to justify expansion of staff, an increase in marketing effort is needed, requiring more staff.

VI. FURTHER ANALYSIS OF MANAGERIAL DECISION MAKING FOR AN ISS

A discussion of developments in the market for scientific and technical information offers additional perspectives on the situation of the ISS managers. The decline in batch oriented systems for the dissemination of STI (SDI services) spawned much activity in the information science field related to investigating the applicability of on-line techniques for STI dissemination. The new technique changed the nature of the information service provided; the subscription orientation was replaced by a demand search orientation, similar in concept to a "retrospective search". Demand search added the capability of providing interaction and modification of the query during the actual search.

The economics of the new technique proved discouraging. Firstly, the hardware itself was relatively costly even for providing only a minimal service. Secondly, the cost for the information bases and their indices increased significantly. As a consequence of the economic difficulties for small independent centers, a market structure developed where the maintenance of the large information bases relied on a relatively small number of "information wholesalers", who also provide the information processing resources needed for searching (Gardner et al., 1974, p. 2). The ISS's studied here are "information retailers", and the ISS management are limited to external development of software for the service and information acquisition.

The purpose of this section is to discuss possible managerial actions and their effects, given the limitations dictated by the structure of the STI market and the determinants for staff hiring as modeled previously.

Different emphasis on marketing

Marketing is sometimes considered the "cure all" for ISS's. It is true that the typical ISS has insufficient marketing resources, but if marketing is over-emphasized, an adverse effect on delivery delays can emerge to limit resources even more necessary to compensate for the relatively long delivery delay.

Figure 12 shows the result of a simulation run indicating too much emphasis on marketing and assistance. The number of users grows initially as fast as in the reference run (note that the scale in Figure 12 is different) then levels out just over 900. The number of users does not decline in spite of the adverse effects from the long delivery delay, since the effect from marketing and assistance on entry rate is relatively high. The long delivery delay leads to a strong need to expand staff but also reduces the funder's willingness to support the service. The ISS is also hindered from expansion by the economic constraint because of the low volume of queries per staff. The result is a "marketing trap" with the long delivery delay reducing the users' propensity to querty. As a consequence the marketing effort must increase to attract more users to compensate for the low propensity to query. However, such an increase diverts resources from production and the delivery delay situation would worsen.

The change made in the simulation to give Figure 12 reflects an increase in the indicated need for staff to marketing in loop U5. There are, however, other ways for management to emphasize marketing; the change in allocation of resources (loop Q7) can be made more slowly. This means that the pressure to reallocate staff shows that such a policy is not advisable. The immediate effect is that delivery delays increase - indicating a need for more staff, which is effected by hires (loop S10). The expansion is not hindered by a reduction in the funder's willingness to support the service (loop S11) since the funder requires a relatively long time to form an opinion about the quality of the service. The growth in both users (loop U2) and queries (loop Q6) is retarded, and the economic constraint (loop S12), together with at reduced willingness on the part of the funder (loop S11), will soon result in a reduction of staff. After this reduction the behavior of the model is similar to the reference run, but the result of the operations during the 240 weeks is worse in both users and queries. Short term successes in terms of staff expansion are counteracted by market responses.

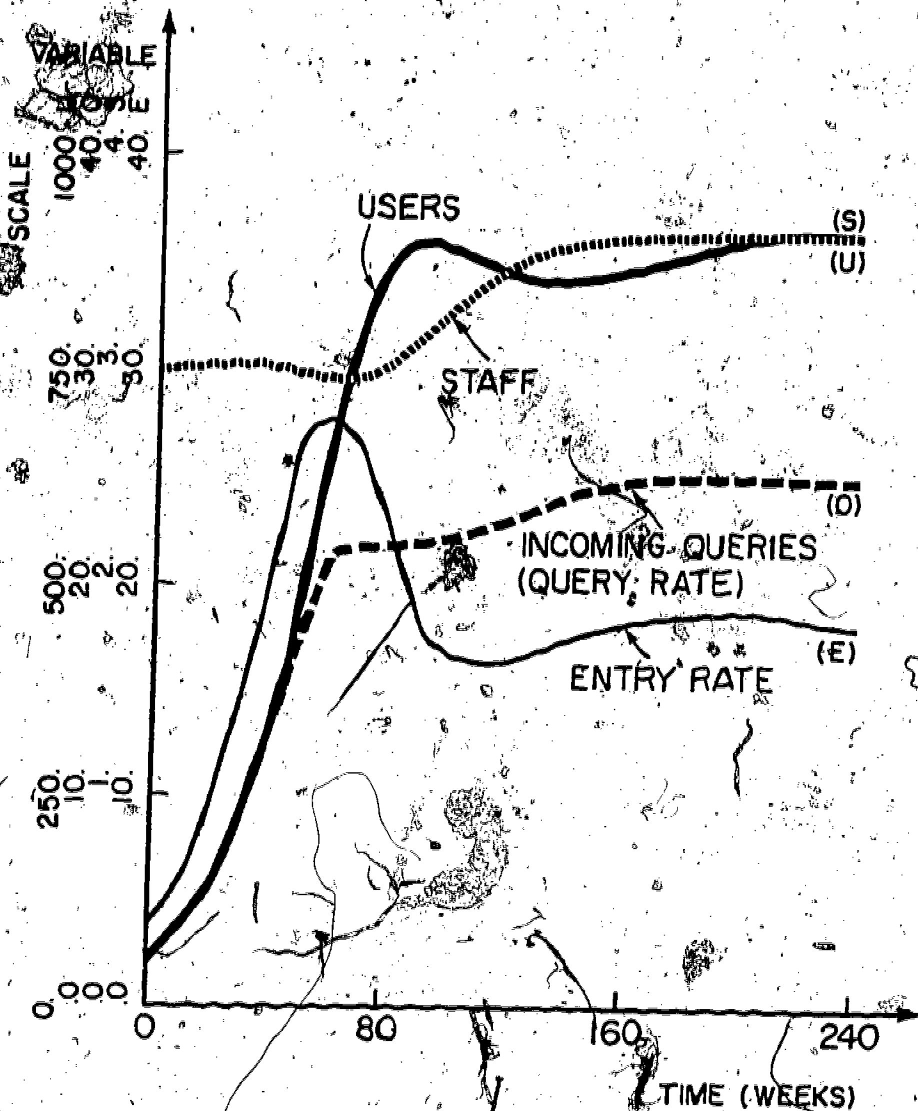


Figure 12
Simulation result when marketing is overemphasized

Changing the size of the user population

The size of the potential market can be governed by the institutional setting, and it might not be possible to impose discriminatory rules regarding who may and may not become a user. It is common, however, to allow the ISS to extend the potential user population beyond the boundary of its organizational host, and this policy is sometimes applied to increase growth. Simulation runs with the ISS model show that this policy gives no significant improvement. When the size of the potential market is increased, the result is practicaylly identical to the reference run.

Of course, the size of the potential market must be related to the available staff. Initially the number of staff for a typical ISS is small, which could be taken to indicate that a reduction of the size of the potential market would be better. Simulation runs with the model show that a reduction of the number of potential users from 2 000 to 700 gives better result in qualitative terms, i.e. in terms of assistance given and delivery delay, but since there is no visible need for expansion (loop S10), the staff is not increased. With the staff of three the ISS succeds in attracting 85% percent of the (reduced) potential users.

The actual size of the potential market is difficult to determine exactly. The simulation results indicate a danger in overrestricting the market; so that while an increase in the potential market causes only slight changes in the quantitive results of the ISS operations, at least "normal" expansion is possible.

User education.

User education has always been considered a part of the marketing of ISS's. One reason for this is that an ISS, like many other services, considers it as its responsibility not only to help people but also to help them help themselves. Another reason is that an educated user has more realistic expectations regarding the information search service.

With regard to delivery delay in particular, overexpectation has been common. The general tendency to overestimate the speed of computerized processes is part of the reason for this, but the ISS's have also reinforced the impression by appealing to this bias in their advertising and marketing. The resulting disappointment effect, when it becomes clear that the ISS does not give "instant access" to the literature, is greater than it need be.

The simulation model was run with reduced sensitivity to delivery delay on the part of the potential users, i.e. delivery delay has less effect on the decision to become a user. The result of this simulation is given in Figure 13, and shows a significant improvement compared to the reference run.

With the potential users being less sensitive to delivery delays, actual use is not discouraged, and the ISS retains more of its business in spite of a decrease in the propensity to query so that expansion is possible. Staff grows to 5.5 at the end of the 240 weeks and the number of users is 1450. The ISS gets 43.5 search requests per week and 32 new users enter the service weekly.

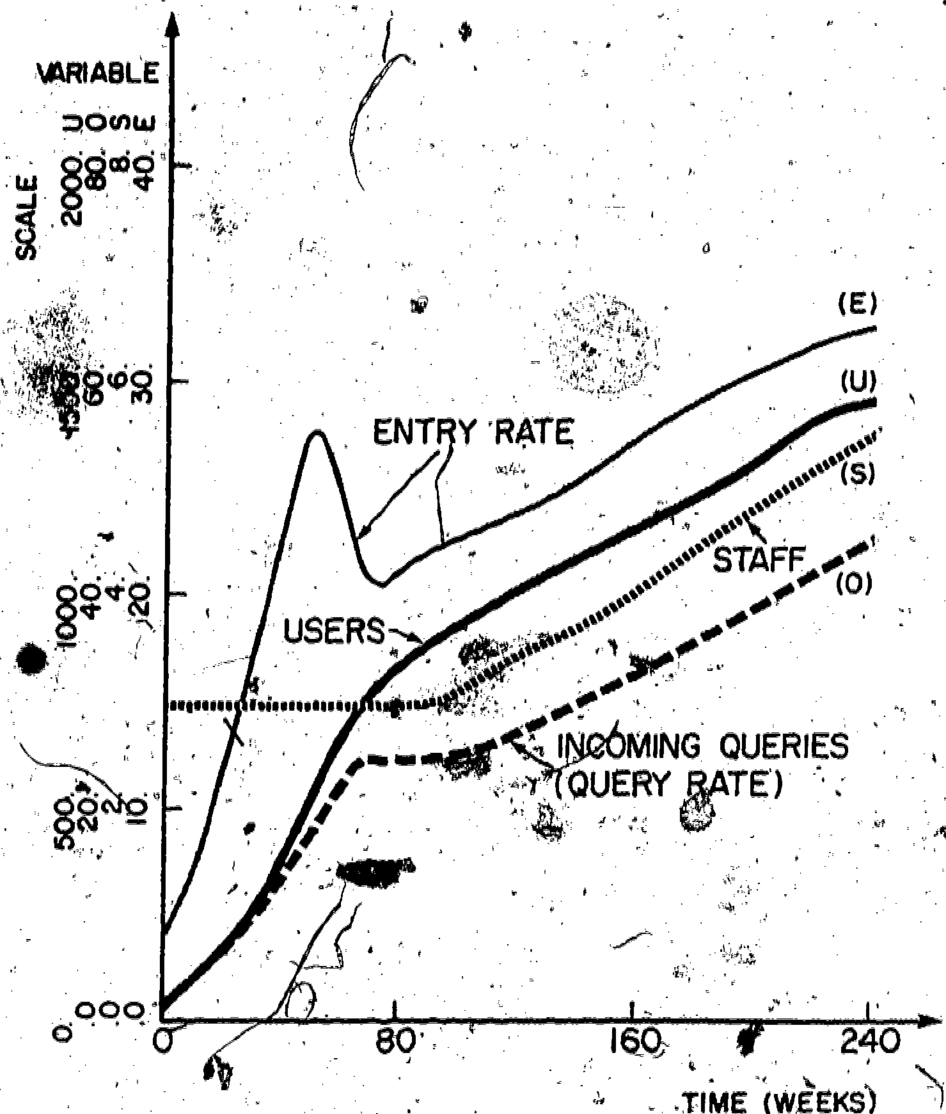


Figure 13
Simulation result when the sensitivity to delivery delay is reduced

The growth curve for the number of users in Figure 13 has a "kink" around week 65 but the leveling off is not nearly as dramatic as in the reference run. The quantitative results from the simulation compare favorably with a simulation where the funder imposes no constraints on the expansion of staff. In other words, the negative effects from overexpectation regarding delivery delay can inhibit growth almost as much as the funder's constraints. This emphasizes the importance for ISS managers that the marketing messages and user education programs convey a realistic picture of expectations in terms of delivery delays.

VII. CONCLUSIONS FROM THE SIMULATION EXPERIMENTS

From this analysis of information search services and from the computer simulations of the ISS model we can draw the following conclusions:

1. The often experienced decline in growth in the number of users can be explained as a natural consequence of market responses to the ISS operations.

2. The ISS management is in a contradictory situation where long delivery delays provide justification for expansion but inhibit growth. A reduction in the sensitivity to delivery delay, by appropriate marketing and user education, is an effective way to alleviate this problem.

3. Marketing is not a cure-all for ISS's and over-emphasis on marketing can be harmful for the growth of the ISS, especially if the funder has a constraint relating to the volume of business per staff, in which case there is a potential "marketing trap".

4. Increasing the size of the potential market might not lead to a significant increase in growth, but a sufficiently large market is important in assuring "normal" growth.

CHAPTER THREE
ISS2 MODEL DESCRIPTION - A THEORY OF ISS GROWTH

The description of the ISS/user/funder system that was given both verbally and in form of causal loop diagrams in the former part of chapter two was the basis for the development of the simulation model ISS2. Based on results from simulation experiments with this model the analysis and conclusions of the latter part of the chapter were made.

ISS2 is a system dynamics model. This methodology is described by Forrester (1961, 1968), Goodman (1974) a.o. The language used for the simulations is DYNAMO II, which is described in Pugh (1973).

II MODELING TOOLS

Conceptually a system dynamics model is a system of differential equations of the following form:

$$\underline{R} = \frac{d\underline{L}}{dt} = F(\underline{A}) \qquad (1)$$

$$\underline{A} = G(\underline{L}) \qquad (2)$$

where $\underline{L}$ is the vector of "levels", $\underline{R}$ is the vector of "rates", $\underline{A}$ is the vector of "auxiliary variables" and t is time.

A level represent an accumulation of resources or information, e.g. employees, a backlog of orders or a population of customers. A rate describes activities in a system such as flow of money, streams of information, shipment of goods. An equation defining a rate represents a decision in the system. An auxiliary variable is used to break down the decision function into more detailed parts, which sometimes is needed for clarity.

Equations (1) and (2) can be represented by a feedback loop (Figure 1) with the arrow from rates to levels representing integration.

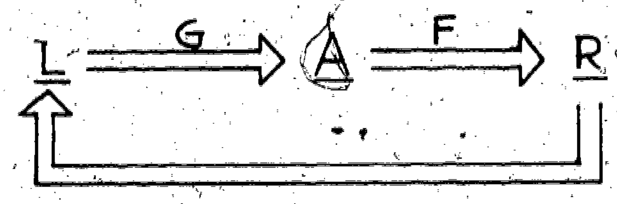


Figure 1

Consider a tank of water with both inflow valves and outflow valves as an example. The inflow rate causes the level of water to rise and the outflow rate causes it to be lower. At any point in time the level of water is equal to the initial level plus the net effect of the inflow and outflow up till that time. Thus the water level is given by:

$$L_t = L_0 + \int_0^t (IF - OF)\,dt \qquad (3)$$

where L_t is the level of water at any given time t
L_0 is the initial level of water (at time t=0)
IF is the inflow rate
OF is the outflow rate
dt is the differential operator.

As implemented on a digital computer the process of integration is in DYNAMO approximated by first-order difference equations, called level equations, of the following form (Pugh, 1973, p. 3):

[illegible] (IF.JK - OF.JK) (4)

where the period (.) is used to separate the variable names from the time indices and

L.K = new value of level (at time = K)

L.J = previous value of level (at time = J)

DT = the elapsed time between time = J and time = K

IF.JK = the value of the inflow rate during the interval JK

OF.JK = the value of the outflow rate during the interval JK

In order to compute the actual value of the level the equations defining the rates must also be known. The general form for a rate equation is:

R.KL = f (levels) (5)

When the values of the levels have been computed at time K the rates for the succeeding time interval, KL, can be determined. The function f can be any function of levels. Taking, again, the watertank as an example the outflow rate could be proportional to the amount of water in the tank. If the water tank is part of a system with human operators the inflow rate could depend on how much the volume of water in the tank differs from a desired volume.

In this latter case the inflow rate depends on the operators decision, and the rate equation is a policy statement that describes how decisions are made. It is common in system dynamics to let the terms "decision" and "policy" have a broad meaning:

> "They go beyond the usual human decisions and include the control precesses that are implicit in system structure and in habit and tradition. A rate equation (or policy statement) might describe how the hiring rate in a firm

depends on the level of vacancies and the level of available unemployed. A rate equation could also represent the subjective and intuitive responses of people to the social pressures within an organization; a rate equation might represent the explicit policies that control inventory ordering on the basis of current inventory and average sales rate.

The rate equations are more subtle than the level equations. The rate equations state our perception of how the real-system dicisions respond to the circumstances surrounding the decision point. (Mass, 1975, p. 164)

Flow diagrams

When developing a system dynamics model, flow diagrams are often used. In these diagrams a level is represented by a rectangle and a rate variable by a valvelike symbol. Circles represent auxiliary variables. An example of a flow diagram is given in Figure 2.

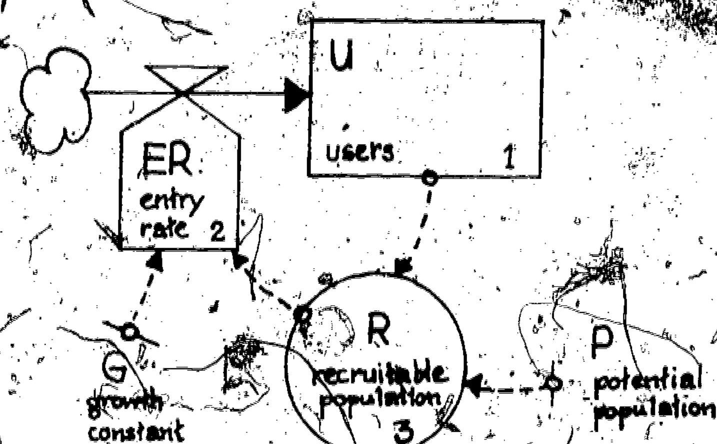


Figure 2
Example of DYNAMO flow diagram.

In this example the solid arrow through ER into U represents the flow of users. The arrow starts in a cloud-like symbol which is called a "source". Here there is only an inflow of users but if there had been an outflow as well this would have been represented by an arrow going into another cloud-like symbol which then would have been called a "sink". Information links are illustrated by dashed arrows going from any level or auxiliary variable to each auxiliary variable or rate affected by it. Information "take-off" is shown by a small circle. Constants are drawn as short solid lines next to the name of the constant. In Figure 2 we see that the recruitable population R depends on both the current number of users U and the potential population P.

The number in the symbols for levels, rates, and auxiliaries is the number of the equation defining the respective variable.

Documentation equation format

For presentation of a system dynamics model the DOCUMENTOR program (Pugh, 1973) provides a model listing with definitions of quantity names, and information about equation number and type. The model in Figure 2 would appear as follows in the DOCUMENTOR format:

```
U.K = U.J + (DT)x(ER.JK)                  1, L
U = UN                                    1.1, N
UN = 0                                    1.2, C
        U   - USERS (USERS)
        ER  - ENTRY RATE (USERS/WEEK)
        UN  - INITIAL NO. OF USERS
```

```
ER.KL = R.K x G                          2, R
G = 0.0374                               2.1, C
     ER   - ENTRY RATE (USERS/WEEK)
     R    - RECRUITABLE POPULATION
            (USERS)
     G    - GROWTH CONSTANT (FRACTION/
            WEEK)

R.K = P - U.K                            3, A
P = 2000                                 3.1, C
     R    - RECRUITABLE POPULATION
            (USERS)
     P    - POTENTIAL POPULATION
            (USERS)
     U    - USERS (USERS)
```

The first line of this example is the equation defining the number of users, which is a level, at any given time K. This number is equal to the number of users at the previous point in time J plus the value of the entry rate ER during the time interval JK multiplied by the length of the time interval DT. The "1, L" to the right of the equation is the equation number and type. The equation number can also be found in the flow diagram in Figure 2 in the level for users U. Equation type can be one of the following:

L denoting level
N denoting initial value of level
R denoting rate
A denoting auxiliary
C denoting constant
T denoting tablefunction

The second line of the example is an initial value assignment indicating the initial number of users to be equal to the constant UN, which is specified in the next line as a constant having the value zero.

The variable names appearing in the equation are then listed together with their definitions. In parentheses are given the units of measurement.

The fourth equation of the example ("2, R") is a rate equation describing the entry rate ER. It says that for each coming time interval of unit length the entry rate is equal to a growth constant times the number of recruitable users R. The units for ER is users/week but this does <u>not</u> mean that the soultion time interval DT is one week: DT is specified separately as a control parameter for the execution of the simulation program and specifies the time between successive calculation of the values of the model variables. Since the growth constant is equal to 0.0372 the entry rate, measured in users/week, is equal to 0.0374 times the number of recruitable users.

Equation 3 is an auxiliary equation indicated by "A" to the right. It defines the recruitable population as the difference between the potential population P and the current number of users U.K.

Equations 2 and 3 illustrate the use of auxiliary equations: it would have been possible to define the equation for the entry rate directly as ER.KL = (P - U.K) x G. In this simple example perhaps clarity is not lost but when the equations are more complex this can happen.

The example discussed above is a system dynamics adaptation of a dynamic model presented by Ware ([illegible]3) for characterizing the growth patterns of data base utilization. Ware's growth model is based on the following first-order equation:

$$\frac{dU}{dt} = G \times (P - U) \qquad (6)$$

The notation has been transformed to conform with the definitions given above. The correspondence between the system dynamics model and the differential equation is easier to see from the following set of equations:

$$ER = \frac{dU}{dt} = G \times R \qquad (7)$$

$$R = P - U \qquad (8)$$

This is also a practical illustration of what was said initially about the conceptual foundation of system dynamics being a system of differential equations of the form given by equation (1) and (2) which are reprinted here:

$$\underline{R} = \frac{d\underline{L}}{dt} = F(\underline{A}) \qquad (9)$$

$$\underline{A} = G(\underline{L}) \qquad (10)$$

where $\underline{L}$ is a vector of "levels", $\underline{R}$ is the vector of "rates", $\underline{A}$ is the vector of "auxiliary variables", and $\underline{t}$ is time.

In the following all equations will be given in the DYNAMO form. Common notations for these equations are summarized as follows.

IN ALL EQUATIONS: time indices are written after the variable name separated from it by a period (.)

TIME INDICES denote both point in times and time intervals according to the following:

J	denotes the previous point in time and is used in level and auxiliary equation
K	denotes the current point in time and is used in level and auxiliary equations
JK	denotes the time interval between J and K and is used in rate equations (and sometimes in auxiliary equations containing a variable that is or will be smoothed - see p. 105)
KL	denotes the time interval between K and the succeeding point in time, L, and is used in rate equations

DT denotes the length of the time interval between successive calculations of the values of the model variables and is used in level equations.

Special Functions in DYNAMO

The DYNAMO compiler can perform a number of special functions (see Forrester, 1968, chapter 8), some of which are used in the model ISS2.

The TABLE function gives the numerical values of a dependent variable as a function of an argument (independent varaible) by performing linear interpolation between points in a table. This is a convenient way of expressing e.g. non-linear relationships between variables. The formats of the equations needed are the following:

DV.K = TABLE(TNAME, IV.K, N1, N2, N3) n, A

TNAME = E1/E2/ - - - /EL n.1, T

where DV.K	is the name of the dependent variable
TABLE	is the function name
TNAME	is the name of the table on which the function is to operate
IV.K	is the name of the independent variable for which the corresponding table entry is to be located (level or auxiliary variable)
N1	is the value of IV.K at which the first table entry is recorded
N2	is the value of IV.K for the last table entry
N3	is the interval in IV.K between table entries
E1	is the value of the table at IV.K = N1
E2	is the value of the table at IV.K = N1 + N3
EL	is the last table entry giving the value of the table at IV.K = N2
n, A	is the equation number and type (auxiliary)
n, 1, T	is the equation number and type (table)

The following figure illustrates the TABLE function:

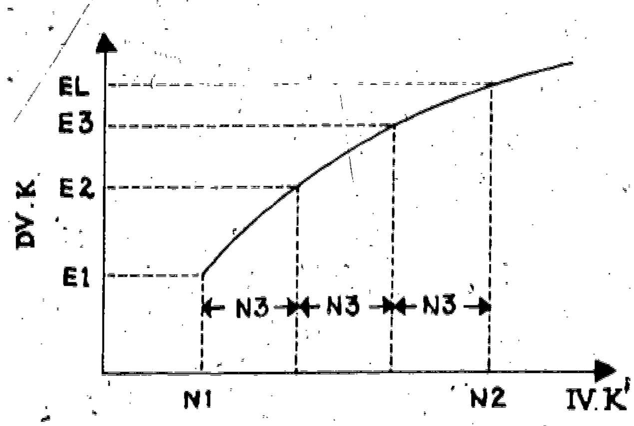


Figure 3

The TABHL function is similar to the TABLE function. The function name stands for TABLE with High-Low extensions. It differs from the TABLE function by allowing the independent variable to be outside the range specified by N1, N2. When the value of IV.K is less than N1 the value of the dependent variables is equal to E1, and when the independent variable is greater than N2 then the value of the dependent variable is equal to EL. The TABHL function has the same arguments as the TABLE function:

TABHL(TNAME,IV.K,N1,N2,N3)

The MIN function is one of the DYNAMO functions that perform logical operations. It is written:

MIN(P,Q)

The SMOOTH function is a first order information delay. The function contains an integration, i.e. a level, and in a flow diagram it is represented by a rectangle.

> "It is used in an information channel to produce a first-order exponential delay. It represents the process of a gradual, delayed adjustment of recognized information moving toward the value being supplied by a source. It is used to generate a delayed awareness of a changing situation" (Forrester, 1968, p. 8-22)

The function is written:

PV.K = SMOOTH(IV.K,DELTME)   n, A

where	PV.K	is the recognized, or perceived, value of the input variable
	IV.K	is the input variable whose value is delayed
	DELTME	is the delay time

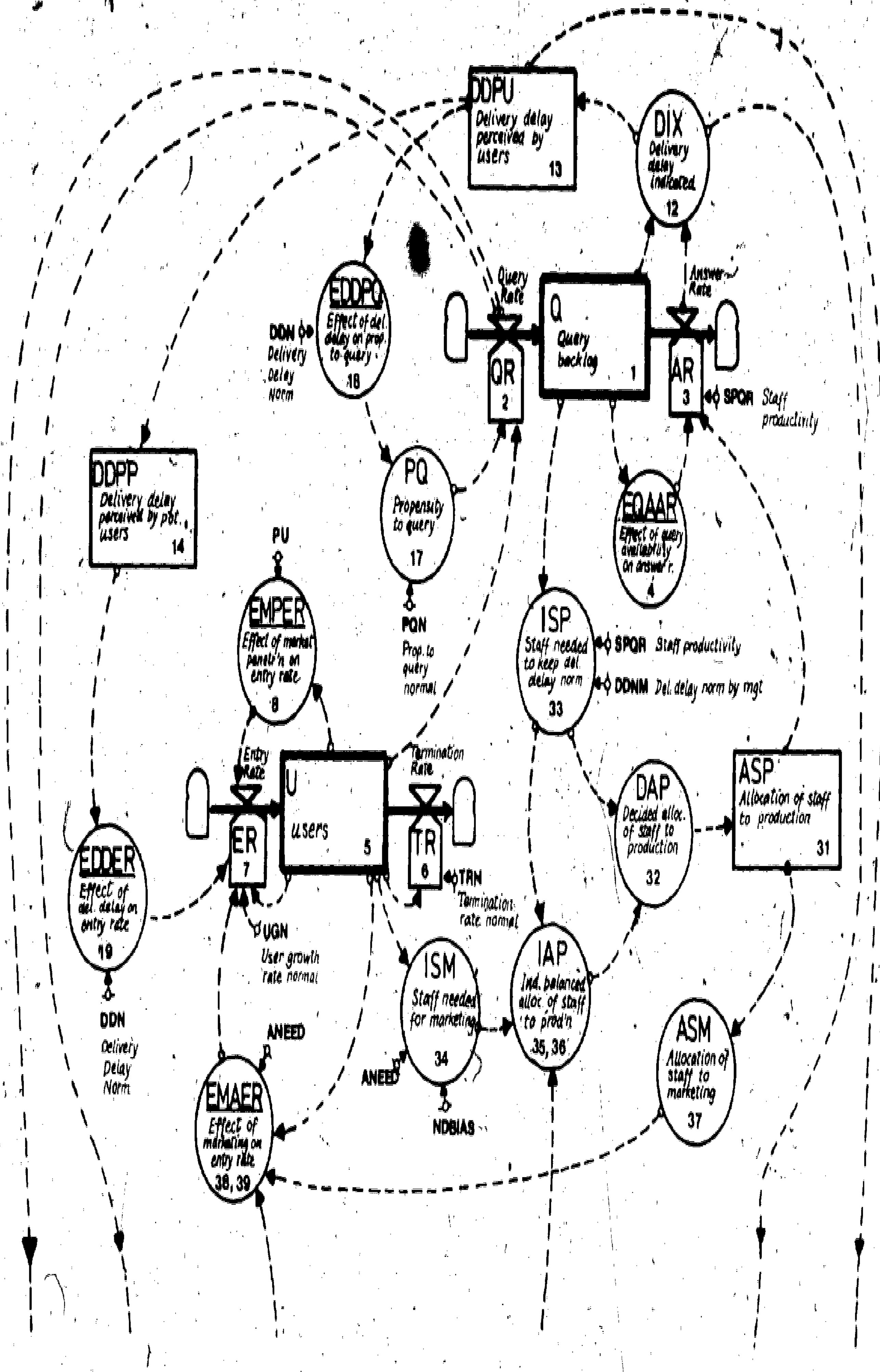


Figure 4
DYNAMO flow diagram of the simulation model ISS2

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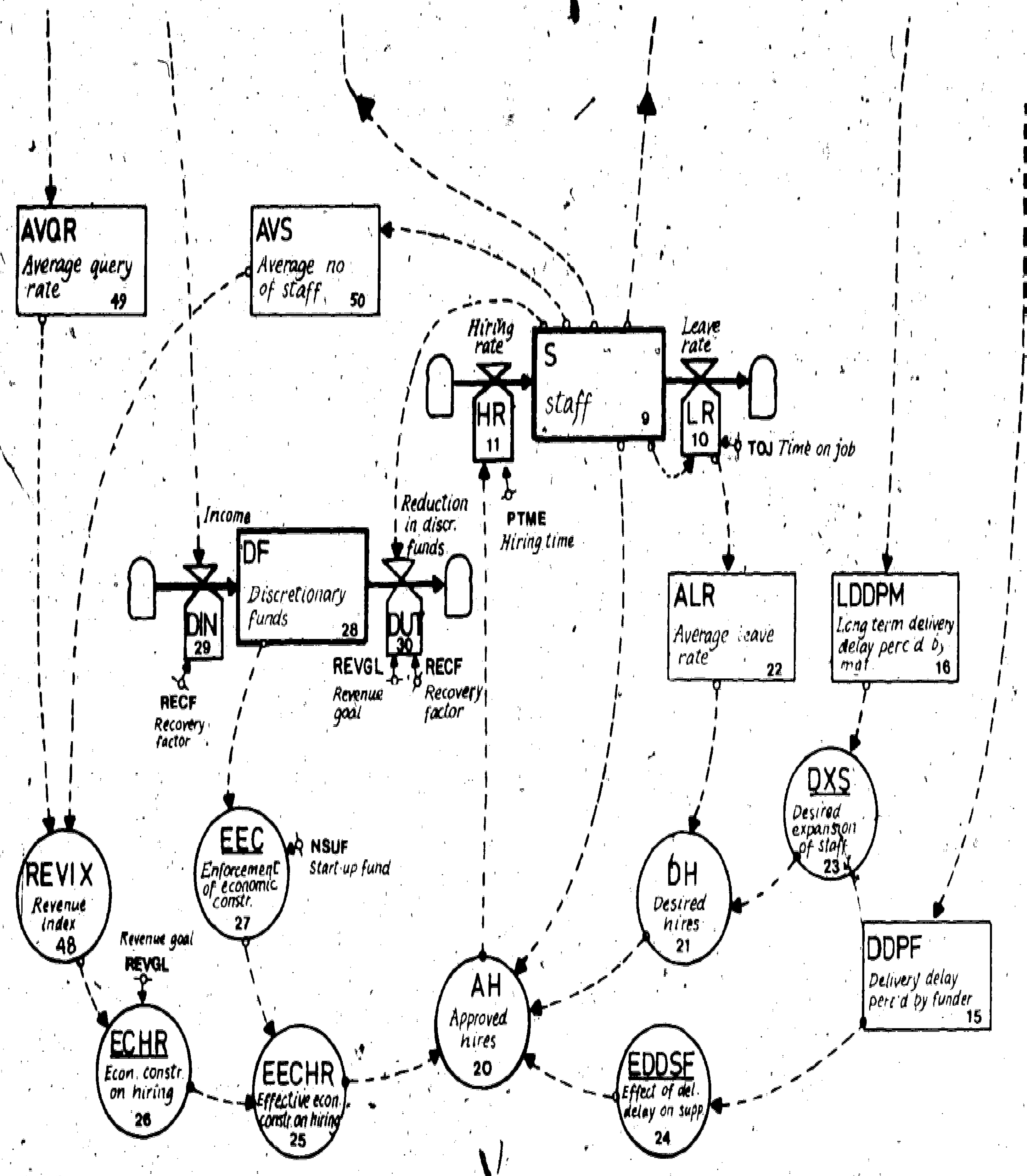

AVQR
Average query rate
49
AVS
Average no of staff
50
Hiring rate
S
staff
9
Leave rate
HR
11
LR
10
TOJ Time on job
PTME
Hiring time
Income
DF
Discretionary funds
28
Reduction in discr. funds
DIN
29
DUT
30
RECF
Recovery factor
REVGL
Revenue goal
RECF
Recovery factor
ALR
Average leave rate
22
LDDPM
Long term delivery delay perc'd by mat
16
DXS
Desired expansion of staff
23
REVIX
Revenue index
48
EEC
Enforcement of economic constr.
27
NSUF
Start-up fund
DH
Desired hires
21
DDPF
Delivery delay perc'd by funder
15
Revenue goal
REVGL
AH
Approved hires
20
ECHR
Econ. constr. on hiring
26
EECHR
Effective econ. constr. on hiring
25
EDDSF
Effect of del. delay on supp.
24

II. DESCRIPTION OF ISS2

The description of ISS2 will be based on a DOCUMENTOR listing of the model. A DYNAMO flow diagram of ISS2 is given in Figure 4. The equation numbers of level, rate and auxiliary equations can be found in the DYNAMO flow symbol representing the variable in question.

One of the basic physical flows contained in ISS2 is the flow of queries, or search requests. Equations 1 - 4 describe how the backlog of queries changes. Equation 1 is a level equation defining the query backlog Q which is increased by the query rate QR and decreased by the answer rate AR. Equation 1.1 is an initial value equation stating that the initial value of the query backlog Q is to be equal to the constant QN which will be specified later.

Equation 2 is a rate equation specifying the query rate QR. Incoming queries depend on two things: the number of users U and their propensity to query PQ. Since both these things will vary with time it is not possible to represent them with constants. The number of users U is a level and the propensity to query PQ is an auxiliary variable, hence the time subscript K. Equation 2 states that the query rate is equal to the number of users times their propensity to query.

Q.K=Q.J+(DT)x(QR.JK-AR.JK) 1, L
Q=QN 1.1, N

Q	-	Query backlog (queries)
QR	-	Query rate (queries/week)
AR	-	Answer rate (queries/week)
QN	-	Initial no of queries

QR.KL=U.K*PQ.K 2, R

QR - Query rate (queries/week)
U - Users (users)
PQ - Propensity to query (queries/week/user)

AR.KL=ASP.K*SPQR*EQAAR.K 3, R

AR - Answer rate (queries/week)
ASP - Allocation of staff to production (staff)
SPQR - Staff productivity (queries/week/staff)
EQAAR- Effect of query availability on answer rate (dimensionless)

The answer rate AR which is specified in Equation 3 is equal to the number of staff allocated to searching, ASP times their productivity SPQR and a minor effect from query availability EQAAR.

In equations 4 and 4.1 the effect of query availability on answer rate EQAAR is defined using the TABHL function (see page 105). We know that when there are no queries at hand it is not possible to produce an answer. It is also possible that a very low volume of queries will lead to an increase in the scheduling delay which leads to a decrease in productivity. The reason for this is that the average waiting time will increase when query backlog is very low since only a part of the information base is available at any one time and a query must wait until the relevant part is available. The value of EQAAR should therefore be one when the query backlog has reached a certain magnitude, and from equation 3 we see that in this case the answer rate AR will be equal to the number of staff allocated to production, ASP, times their productivity. When query backlog is zero EQAAR is zero. The consequence of this is that when there are no queries the answer rate AR will be zero regardless of the number of staff allocated to production. EQAAR can then be represented by a table function illustrated in Figure 5:

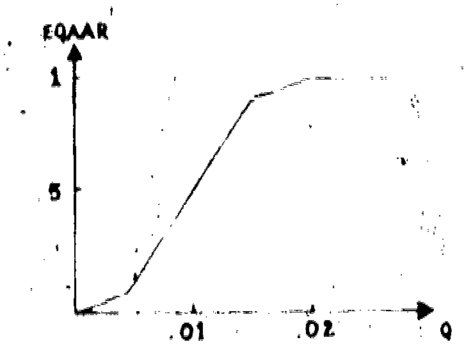

Figure 5.

The effect of query availability on answer rate.

We have found no reference to the productivity-decreasing effect of query availability in the literature, and it is likely that this effect is very small compared to the effect of a change in staff allocation. EQAAR therefore has the value one for all values of Q except close to zero where it declines towards zero, which it must by physical necessity.

In equation 4.1 the table TEQAAR is specified. Together with the parameters for the TABHL function in equation 4 we get the following numerical representation of the table in Figure 5.

EQAAR	0	[illegible]	0.5	0.9	1.0
Q	0	[illegible]	.010	.015	.020

```
EQAAR.K=TABHL (TEQAAR.Q.K,0,0.02,0.005)        4, A
TEQAAR=0/.1/.5/.9/.                              4.1, T
SPQR=10                                          4.2, C

    EQAAR     - Effect of query availability on
                answer rate (dim. less)
    Q         - Query backlog (queries)
    SPQR      - Staff productivity (queries/
                week/staff)
```

The number of queries a staff member can answer in a week depends on how much time is spent on each one. The direct search time seems to vary greatly depending on the philosophy of the ISS: some services spend relatively little staff time per search, whereas others spend a great deal. One hour seems to be a typical search time which is indicated by the SDC impact study (Wanger et al., 1976, p. A-9), but the very short time at the terminal (mean value 19.1 minutes; median value 15.3 minutes) reveals that the search requests must be of a relatively simple kind. The corresponding time for the NASIC service at MIT is almost double (mean value 37 minutes (Benenfeld et al., 1975), and another ISS operating in a university and research environment, the Royal Institute of Technology IDC, gives an average search time of 2.9 hours (Hjerppe, 1977).

Based on these considerations we conclude that for an ISS operating in a research environment and dealing with relatively complex search requests the number of searches per staff per week must be less than 20, and that a feasible long-run average is about 10. The SDC impact study (Wanger at al., 1976, p. B-14) gives a mean value of searches performed in a week of 9.6.

In equation 4.2 staff productivity measured in queries/week/staff, SPQR, is set to equal ten.

Equations 5 - 7 specify the number of users and how they change. In this model all effects on entry and termination rate have been aggregated into multipliers for the entry rate only. This has been done to keep the model simple. Since we are not interested in keeping track of individual users but rather the flow of users a decrease in entry rate is equivalent to an increase in termination rate.

```
U.K=U.J+(DT)x(ER.JK-TR.JK)                              5. L
U=UN                                                    5.1, N

     U     - Users (users)
     ER    - Entry rate (users/week)
     TR    - Termination rate (users/week)
     UN    - Initial no. of users

TR.KL=U.KxTRN                                           6, R
TRN=0.02                                                6.1, C

     TR    - Termination rate (users/week)
     U     - Users(users)
     TRN   - Termination rate normal (fraction/
             week)

ER.KL=(U.K)(UGN)(EMAER.K)(EDDER.K)(EMPER.K)             7, R
UGN=0.0374                                              7.1, C

     ER    - Entry rate (users/week)
     U     - Users (users)
     UGN   - User growth rate normal (fraction/
             week)
     EMAER- Effect of marketing and assistance on
             entry rate (dimensionless)
     EDDER- Effect of delivery delay on entry
             rate (dimensionless)
     EMPER- Effect of market penetration on entry
             rate (dimensionless)
```

Equation 5 defines the number of users U as a level which is increased by the entry rate ER and decreased by the termination rate TR. The initial value of the number of users is determined as being equal to the constant UN. This is specified in the initial value equation 5.1.

The termination rate TR is defined in equation 6 as the product of the number of users U and a termination rate normal TRN. In equation 6.1 TRN is set to equal 0.02. This means that each week 1/50 of the users leave the service or, expressed differently, that a normal time to remain a user is about one year. Such a short time reflects the relatively high turnover of people and changes in interest characteristics typical of an academic setting. The termination rate is difficult to measure since there is no formal contract which has to be canceled; a user will be invisible to the ISS between the times he submits a query. In this study we have chosen not to try to estimate the physical termination rate but adopt to the approach of defining a user as someone who decides to use the ISS and then consider him a user for a normal user time of 50 weeks (see page 59). In the yearly statistics kept by operational ISSs individual users are typically not traced so our approach is consistent with practice which makes it easy to compare simulation results with published statistics.

In this model all effects on entry and termination rate have been aggregated into multipliers for the entry rate only. This has been done to keep the model simple. Since we are not interested in keeping track of individual users but rather the flow of users a decrease in entry rate is equivalent to an increase in termination rate.

Equation 7 defines the entry rate ER as a product of five terms. The first two terms represent the undisturbed growth of the number of users and the remaining three terms representant inhibiting forces. The inflow of users then is stated in terms of a normal growth rate which is modified by multipliers that represent the deviation of the actual system state from the normal with regard to delivery delay (EDDER) and the amount of marketing and assistance given (EMAER). In addition the normal growth rate is modified by a multiplier representing the effect of market penetration EMPER.

The user growth rate normal UGN is specified in equation 7.1 as being equal to 0.0374. This value is based on the experiences at the University of Georgia Computing Center and other information centers.

It is, however, not a trivial matter to estimate UGN. For ISSs, as for many other growth rates, observed values are a function of many variables. In this study the factors affecting the growth rate have been reduced to three major influences, as seen in equation 7, that modify the normal, or inherent, growth in the number of users. Of these three one represents a market saturation effect (EMPER) and the other two are multipliers representing the effect of a deviation of the system state from a "normal" state with regard to delivery delay (EDDER) and the amount of marketing and assistance provided (EMAER).

We can ignore the market saturation effect when looking at the initial growth. Since data on UGN is not available we have to find a proxy. The main consideration for shoosing among available statistics is that the growth of users should be as "undisturbed" as possible. For example, a change from a free service to one that costs money will disturb the growth pattern.

We believe that the data from the University of Georgia Computing Center is the best available even though the service is an SDI-service. From the account of the center's operations given by Carmon (1973) we can infer that the amount of marketing and assistance was adequate but not excessive: the introduction of the service was preceded by an earlier attempt which failed "due to the lack of professional staff to interface with the users" so when the service was restarted "a full-time staff, although small, was employed". Furthermore communication with the center was done via a terminal network and "the computer facilities had already found relatively widespread acceptance and use" from which we can assume that the delivery delay situation was satisfactory.

Carmon presents several diagrams of growth. Of these we have chosen the growth of users for the CA Condensates data base (this diagram can also be found in (Ware, 1973, Fig. 2). The reason is twofold: the diagram is one of the least aggregated, and the CA Condensates data base is comprehensive enough to be a basic adequate information service in one subject field (chemistry).

In Ware's (1973) paper a saturating growth model has been used to interpret the data (see the example on pp. 99–102). Experiences from other services, especially those offering on-line services (i.e. ISSs), indicate that at least initially the growth is exponential (see for example the statistics from NASIC/MIT and RIT-IDC in Figures 1 and 2 on p. 53 and 54). To get an estimate of the natural growth rate UGN we therefore have to reinterpret the data. We do this by estimating the doubling time graphically as shown in Figure 6, where the circles are the observed data points reported by Ware (this part of the figure is copied from Ware's graph).

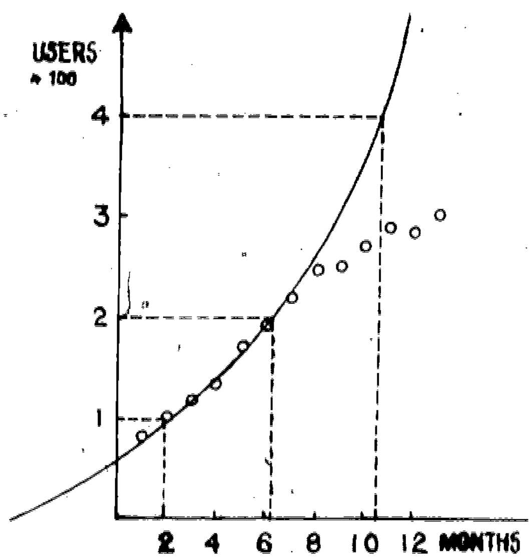

Figure 6
Graphical estimation of doubling time.

The estimated doubling time for the number of users is 4.25 months which gives a growth constant of 0.0374 +).

+) Multiplying this with 52/12 to get weeks of equal lenght we get a doubling time of 18.4 weeks. Since the doubling time for an exponential growth process is 0.69 times the time constant for the process (see e.g. Goodman, 1974, p. 22) we find the time constant to be 26.7 weeks, and consequently the growth constant 0.0374 since it its the inversion of the time constant.

In equation 8 the effect of market penetration on entry rate EMPER is described. This effect depends on the fraction of users to potential users, and represents the increasing difficulty in recruiting new users as more and more potential users have actually decided to become users. Since EMPER occurs as a multiplier in Equation 7 we want it to have the value one when the number of users is zero, i.e. there will be no effect from market penetration initially. When all potential users have become users, i.e. when U/PU equals one, EMPER should have the value zero since the entry rate must be zero. The table function defining EMPER is shown in Figure 7.

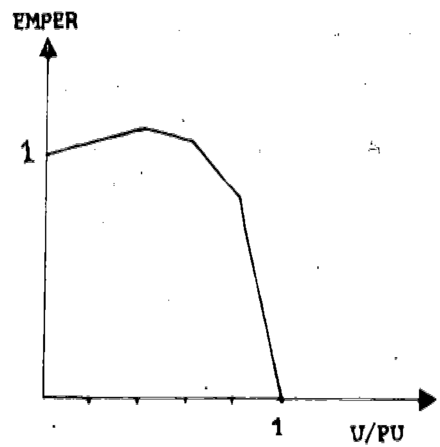

Figure 7

The effect of market penetration on entry rate.

The table defined in equation 8.1 will together with the parameters for the TABLE function in equation 8 represent Figure 7 with the following value pairs:

EMPER	1	1.05	1.1	1.05	.80	0
U/PU	0	0.2	0.4	0.6	0.8	1

```
EMPER.K=TABLE (TEMPER,U.K/PU,0,1,0.2)          8, A
TEMPER=1/1.05/1.1/1.05/.80/0                   8.1, T
PU 2000                                        8.2, C
```

EMPER- Effect of market penetration on entry rate (dimensionles)
U - Users (users)
PU - Potential market (users)

The initial increase and subsequent decrease in the function in Figure 7 represents an additional effect due to the fact that the probability of a user to come in contact with a potential user, i.e. the word-of-mouth effect, at first increases with an increase in the number of users and then decreases. The word-of-mouth effect is important, as found in the NASIC/MIT project (Benenfeld et al., 1975, p. 1-4): "Awareness about the service is most often achieved by word-of-mouth." To an extent this effect is inherent in the exponential formulation of the entry rate. However, compared to the situation at the University of Georgia, for an ISS that starts the service without a previous attempt to introduce the service the world-of-mouth effect could contribute to the normal growth rate. This additional effect we assume not to be more than 10%.

When approximately 2/3 of the market is penetrated it becomes more difficult to attract users, which is represented by decrease in the value of EMPER from unity to zero. The implicit assumption in the shape of the table function is that when both the delivery delay situation and the amount of marketing and assistance provided are normal, i.e. EDDER and EMAER are equal to one, then growth in the number of users will level off when about 85% of the market is reached.+ To achieve a higher market penetration EDDER or EMAER must be higher than one.

The size of the potential user market is given in equation 8.2 as being 2 000. The typical ISS we model is part of a reasonably large academic institution, and the value of PU is based on a personal communication from the NASIC/MIT office (May, 1976). Wish and Wish (1975) made a survey at the University of Wisconsin which gave an estimate of about 1 000 potential users among the faculty. To this graduate students must be added.

> "If librarians want to establish their libraries as information service centers, then customer satisfaction must be sought by offering speed and ease of access to information storage as well as professional expertise, perhaps for an added fee." (Wish and Wish, 1975, p. 3.)

The remaining two factors in the equation for the entry rate ER (equation 7) are the multipliers EDDER and EMAER representing the effect of delivery delay and the amount of marketing and assistance provided, respectively. The multipliers are built around a normal state of the system with regard to these two major service characteristics. The actual state of the system is compared to a norm and the multiplier represents the effect of deviations from this norm. Further examples of the modeling technique of using normal values can be found in (Forrester, 1968, p. 23 ff.).

+). Recall that the termination rate for users is 0.02. When the effective entry rate equals the termination rate growth will level off. This will happen when EMPER = 0.5348, and the value of U/PU will be 0.8664.

The effect of delivery delay on entry rate is specified in equation 19 as a TABLE function, and the corresponding table is given in equation 19.1

```
EDDER.K=TABLE (TEDDER, DDPP.K/DDN,0,3,0.5)        19.A
TEDDER=1.6/1.47/1/.47/.3/.3/.3                    19.1, T
DDN=0,5
```

EDDER - Effect of delivery delay on entry rate (dim. less)
DDPP - Delivery delay perceived by potential users (weeks)
DDN - Delivery delay norm (weeks)

The dependent variable for the TABLE function is the ratio of delivery delay perceived by potential users, DDPP, to delivery delay norm, DDN. The higher this ratio is the worse is the service perceived. When the perceived delivery delay equals the norm, i.e. DDPP/DDN = 1, then the value of the multiplier is by definition one. Should the perceived delivery delay be shorter than the norm then DDPP/DDN is less than one, and the value of the multiplyer should be greater than one. The actual table function used in ISS2 is shown in Figure 8.

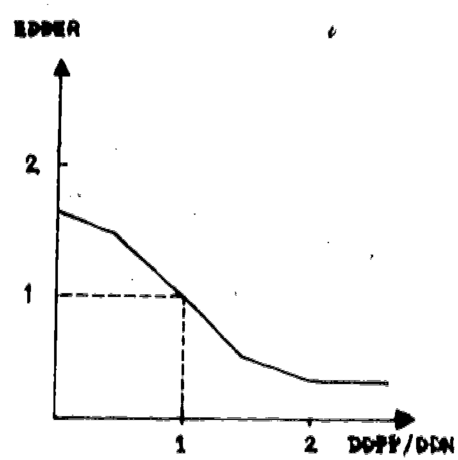

Figure 8
The effect of delivery delay on entry rate.

Equations 19 and 19.1 give the following value pairs as the representation of this table:

EDDER	1.6	1.47	1.0	0.47	0.3	0.3	0.3
DDPP/DDN	0.0	0.5	1.0	1.5	2.0	2.5	3.0

Around the normal point (1.1) the curve in Figure 8 is assumed to be linear with a slope of about -1. That is to say that the effect is proportional to the change in DDPP/DDN. This assumption was not based on empirical observations since it is very difficult to analyse effects due to delivery delay in isolation: when the delivery delay increases the ISS is overloaded and has typically already tried ~~to~~ compensate this by reducing the amount of marketing and assistance. The assumption, however, is indirectly supported by experiences at the Library of Congress, SCORPIO service (personal communication, March, 1977): the installation of a faster processer in the main computer resulted in a 23% improvement in response time and the increase in the number of searches was between 23% and 35%. (Unpublished statistics for the SCORPIO service revealed an average of 857 searches for the four months prior to the installation of the fast processor. The following month the number was about 1200 with an even higher projection for the next month. Some of the increase had to be attributed to the return of Congress, but 200-300 searches were attributed to the shorter response time.)

The relationship between the delivery delay situation and EDDER is, however, not linear for all values of DDPP/DDN. Even a relatively long delivery delay does not reduce the entry rate to zero as indicated by Hjerppe (1975, p. 123) who gives statistics from the RECON service at RITL-IDC where the average delay between submission of query and search was about 10 days during 1973. Judging from the relatively high satisfaction expressed by the users in spite of the long delivery delay, the effect of this factor will probably grow slower as the delay gets shorter. These considerations are reflected in the kinks in the table function in Figure 8.

The value of the delivery delay norm DDN is given in equation 39.2 as 0.5. In the SDC impact study (Wanger et al., 1976, pp. 221-2) it is reported that over 80% of all search requests were being filled within one week of their receipt. The average delay is 2 days (p. A-24) but if there is an appointment system, which we assume for the typical ISS in an academic setting, this time will have to be lengthened somewhat (cf. Hjerppe, 1975, p. 125). The managers interviewed in the SDC study indicated that 86% of their users were satisfied with the turn-around time. From this dicussion we infer that half a week is a reasonable norm for delivery delay.

The remaining term in the equation for the entry rate ER (equation 7) is EMAER, the effect of marketing and assistance on entry rate. EMAER is specified in equation 39 and 39.1, and like EDDER it is a multiplier representing effects of deviations from a normal situation. The argument for the TABLE function in equation 39 is the ratio of needed to available assistance ASTND/ASM. ASM is the amount of staff allocated to marketing and assistance (see page 147), and ASTND is the needed assistance expressed in number of staff. ASTND is calculated in equation 38 as the product of the number of users and the assistance needed per user (expressed in staff/user), ANEED. The value of ANEED is 0.001 staff per user (equation 38.1) which means that, assuming a 40 hour work week and 48 work weeks per year, that a user requires 2 hours of staff time to be satisfied. In a relatively mature state for an ISS with about 800 users and a staff about 3 persons this means that 28% of the staff time must be spent on marketing and assistance. Experiences from operational ISSs give the actual average values for resources spent on marketing and customer assistance as anything between 10% and 40%. Gardner et al. (1974, p. 6) give examples of explicit policies to allocate a minimum of 15% of the operating budget to marketing efforts, and at the National Library of Canada an estimated 40% of staff effort is spent on marketing and assistance (personal communication, May, 1975).

The effect from marketing and assistance on entry rate is illustrated in Figure 9.

```
ASTND.K=U.KxANEED                                   38, A
ANEED=0.001                                         38.1, C

     ASTND- Assistance needed (staff/week)
     U     = Users (users)
     ANEED- Assistance needed per user (staff/
            week/user)
```

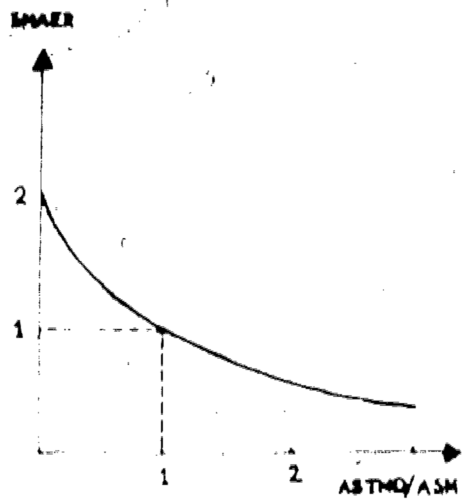

Figure 9

The effect of marketing and assistance on entry rate.

```
EMAER.K=TABLE(TEMAER,ASTND.K/ASM.K,0,3,0.25)          39, A
TEMAER=2/1.55/1.3/1.1/1/.81/.7/.62/.56/.5/            39.1, T
.45/.42/.38
DDN=0.5                                               39.2, C
PQN=0.035                                             39.3, C

     EMAER  Effect of marketing and assistance
            on entry rate (dim. less)
     ASTND  Assistance needed (staff/week)
     ASM    Allocation of staff to marketing
            and assistance (staff)
     DDN    Delivery delay norm (weeks)
     PQN    Normal propensity to query
            (queries/week/users)
```

The table values given in equation 39.1 together with the parameters for the TABLE function in equation 39 give the following value pairs:

EMAER	2.00	1.55	1.30	1.10	1.00	0.81	0.70	0.62	0.56
ASTND/ASM	0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00
EMAER	0.50	0.45	0.42	0.38					
ASTND/ASM	2.25	2.50	2.75	3.00					

The effect from marketing and assistance on entry rate is assumed to be greater than that from delivery delay, and Figure 9 shows that the entry rate could be doubled if there were unlimited resources available for marketing. The table also shows that an allocation of staff to marketing gives increasing returns to scale. That the effect of marketing is in fact dramatic is evidenced by the statistics from RITL-IDC (see diagram on page 54) where the sharp increase in the number of search requests in early 1976 came after a marketing campaign (the increase was from about 75 search requests per quarter to about 125).

Equations 12-16 describe the delivery delay and how it is perceived by the different decision makers. The delivery delay indicated DIX is defined in equation 12 as the query backlog Q divided by the answer rate AR. Being a rate AR cannot be measured readily - rates can only be measured over some period of time - which is the reason for introducing the variable <u>indicated</u> delivery delay. If the answer rate were to be constant for a period of time then the delivery delay could be calculated as Q/AR, which can be illustrated by the following example: suppose there is a query backlog of 15, and that this backlog is sustained by incoming queries, then if the answer rate is 30 queries per week, the delivery delay will be half a week.

The period of time over which DIX is measured can be called the averaging time, or smoothing time, and the process of smoothing information introduces a delay in the flow of information: in order to measure a flow per week one has to wait one week. The users' perceived delivery delay DDPU is a delayed version of the indicated delivery delay DIX as described in equation 13

(see p. 105 for a brief description of the SMOOTH function). The users' perception time UPT is the smoothing time for the SMOOTH function. UPT is set to 13 weeks (in equation 13.1) which is a maturing time for the users' experience, and it is assumed that it takes that long to form a definite opinion regarding the true value of the delivery delay.

```
DDPU.K=SMOOTH(DIX.K,UPT)                          13, A
UPT=13                                            13.1, C

     DDPU - Delivery delay perceived by users
            (weeks)
     DIX  - Delivery delay indicated (weeks)
     UPT  - Users' perception time (weeks)
```

The potential users and the funder do not have a first hand experience of the service so their perception of the delivery delay is based on the users'. The users' communicate their perception of the delivery delay and this communication takes time, which introduces another perception delay in the flow of information about the delivery delay. The perception time for potential users' is assumed to be 26 weeks, and for the funder 40 weeks. Equations 14 and 14.1 define the delivery delay perceived by potential users DDPP as a 26 weeks smooth of the delivery delay perceived by users DDPU. Similarly in equations 15 and 15.1 the delivery delay perceived by further DDPF is formulated as a 40 weeks smooth of DDPU.

```
DIX.K=Q.K/AR.JK                                   12, A

     DIX  - Delivery delay indicated (weeks)
     Q    - Query backlog (queries)
     AR   - Answer rate (queries/week)
```

```
DDPP.K=SMOOTH(DDPU.K,PPT)                                    14, A
PPT=26                                                       14.1, C

     DDPP - Delivery delay perceived by potential
            users (weeks)
     DDPU - Delivery delay perceived by users (weeks)
     PPT  - Potential users' perception time (weeks)

DDPF.K=SMOOTH(DDPU.K,FPT)                                    15, A
FPT=40                                                       15.1, C

     DDPF - Delivery delay perceived by funder
            (weeks)
     DDPU - Delivery delay perceived by users
            (weeks)
     FPT  - Funder's perception time (weeks)

LDDPM.K=SMOOTH(DIX.K,LMPT)                                   16, A
LMPT=26                                                      16.1, C

     LDDPM- Long term delivery delay perceived by
            management (weeks)
     DIX  - Delivery delay indicated (weeks)
     LMPT - Management's long term perception
            time (weeks)
```

Management does not have to rely on the users' perception to find out about the delivery delay, so their long term recognized delivery delay LDDPM is a 26 weeks exponential average (i.e. smooth) of the indicated delivery delay DIX, as defined by equations 16 and 16.1. The implicit assumption here is that management forms a definite opinion about the delivery delay situation with a lag of half a year which we believe is realistic considering that it takes some time before statistics are processed and since there is a natural tendency in an academic setting to regard a year as consisting of two semesters.

The effect of delivery delay on entry rate has already been discussed. In addition to this effect delivery delay also has an impact on the propensity to query PQ, i.e. it can discourage return use without making the user leave the service. Thus at any given time the propensity to query might be different from the normal propensity to query PQN. The value of PQN taken from an OECD study (cited in Ljungberg, 1975, p. 77) is 1.8 queries per year, or 0.035 queries per week as given in equation 17.1. Stated differently this means that there is normally 29 weeks between queries from one user.

PQ.K=PQNxEDDPQ.K 17, A

PQ - Propensity to query (queries/week/user)
PQN - Normal propensity to query (queries/week/user)
EDDPQ- Effect of delivery delay on the propensity to query (dim. less)

PQN=0.035 39.3, C

In equation 17 the propensity to query PQ is given as the product of the propensity to query normal PQN and the effect of delivery delay on the propensity to query EDDPQ. The effect from marketing and assistance on the propensity to query is judged to be negligible on the following grounds: marketing and assistance are crucial for attracting users to the service and the important aspect is to increase the users knowledge about the functions of the system (Persson and Höglund, 1975, p. 63); a change in PQ reflects the response of users already having knowledge about the system and about what to expect. EDDPQ is a multiplier representing effects of deviations from a normal delivery delay situation when the delivery delay perceived by users DDPU is equal to the delivery delay norm (or when DDPU/DDN=1). When the normal situation prevails the value of EDDPQ is one and the propensity to query is equal to the normal propensity to query (see equation 17). EDDPQ is defined by a TABLE function in equation 18, and by the TABLE in equation 18.1.

EDDPQ.K=TABLE(TEDDPQ,DDPU.K/DDN,0,3,0.5) 18, A
TEDDPQ=1.5/1.25/1/.8/.65/.57/.5 18.1, T

EDDPQ- Effect of delivery delay on the propensity to query (dim. less)
DDPU - Delivery delay perceived by users (weeks)
DDN - Delivery delay norm (weeks)

The function defining EDDPQ is illustrated in Figure 10.

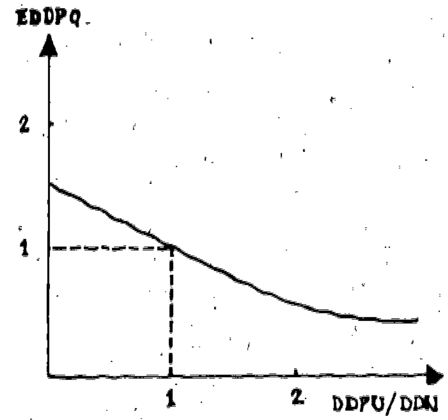

Figure 10
The effect of delivery delay on the propensity to query.

The relative flatness of the curve describing EDDPQ is explained by the fact that EDDPQ is an additional effect on the propensity to query which is primarily a characteristic of the user population.

Equation 18 and 18.1 give the following value pairs:

EDDPQ	1.5	1.25	1.0	0.8	0.65	0.57	0.5
DDPU/DDN	0.0	0.5	1.0	1.5	2.0	2.5	3.0

The effect of delivery delay on the propensity to query has received little attention in the literature but there are some experiences from operational ISSs that can aid the construction of the table. Since EDDPQ is a multiplier with a norm we know by definition the point (1.1). If the propensity to query were constant the table function would be horizontal. This is not the case which is shown by the changes in the percentage of return users. If the propensity to query increases the number of users that will return to the ISS during a year increases too. At the NASIC/MIT service the percentage return users was about 30 at the end of the initial phase (Benenfeld et al., 1975, p. 1-2) and in 1976 it was estimated to be 35% and growing (personal communication, August, 1976).

Another indication that PQ is not constant is that the number of users and the number of searches grow at different rates: the latest annual report from NASIC/MIT (Pensyl, 1977, pp. 5-6) gives a growth in searches of 46% and in users of 33%.

We infer that the users respond to better service by returning more often to the ISS. In terms of the table function in Figure 10 this means that the function will be monotonously decreasing. Since we do not have any further information about the shape of the function we make the simple assumption of linearity with the exception that EDDPQ will not go down to zero. We assume that the effect of delivery delay on the propensity to query is between +50% and -30%.

A decline in the propensity to query as a response to a decline in the service component delivery delay represents one aspect of the voice option on the part of the users, which was discussed on p. 26. The most obvious way to exercise the voice option is to complain to the funder of the service - this aspect is discussed further on p. 136 - but one can also withhold ones queries without leaving the service, thus remaining a user and require staff time for complaints. In the model this is part of assistance needed ASTND (see p. 123). This consequence of the voice option is also discussed by Hirshman (1970, p. 131): "voice can inflict direct costs on management as complaining customers occupy the time of the firm's personnel and succeed in having defective merchandise 'fixed up' or exchanged".

Equation 9-11 describe the number of staff and how it changes. Equation 9 is the level equation and states that the number of staff S is increased by the hiring rate HR and decreased by the leave rate LR. Equation 9.1 is the initial value equation where the initial value of S is set equal to SN.

The leave rate LR, defined in equation 10, is formulated as the number of staff divided by the average time they stay on the job TOJ. Experiences from NASIC/MIT and RITL-IDC indicate that turn-over of staff is low; in equation 10.1 TOJ is set equal to 200 weeks.

```
S.K=S.J+(DT)x(HR.JK-LR.JK)                     9, L
S=SN                                           9.1, N

     S    - Staff (staff)
     HR   - Hiring rate (staff/week)
     LR   - Leave rate (staff/week)
     SN   - Initial no. of staff

LR.KL=S.K/TOJ                                  10, R
TOJ=200                                        10.1, C

     LR   - Leave rate (staff/week)            11, R
     S    - Staff (staff)
     TOJ  - Time on job (weeks)

HR.KL=AH.K/PTME                                11, R
PTME=26                                        11.1, C

     HR   - Hiring rate (staff/week)
     AH   - Approved hires (staff)
     PTME - Hiring time (weeks)
```

The hiring rate HR is described in equation 11 as the number of approved hires AH divided by a hiring time PTME. The hiring time represents the delay necessary for the hiring decision to be effectuated. It includes such components as time to advertize, select candidates, and allow for their notice time. PTME also includes delays inherent in the budgeting process. In equation 11.1 the hiring time is given as 26 weeks, or half a year, which is assumed to cover the delays discussed.

The hiring decision is influenced by both economic concerns and the performance of the ISS in terms of delivery delay. The decision is described in equations 20-27.

The approved hires AH specified in equation 20 are a function of the desired hires DH and the funder's willingness to support the service as well as an economic constraint. To model the expansion decision, i.e. the determinants of AH, on empirical data cannot be done without a considerable data collection effort. Even if such an endeavor was started the nature of the decision making process is fuzzy and involves factors that are very difficult to measure. In this study we have taken another approach: from sources in the literature we extract general trends and attitudes and then formulate the components of the expansion decision in accordance. The factors affecting the decision should then be regarded as <u>examples of policies</u>. The consequence for the study is that the conclusions that can be made are not absolute but contingent on these hypothetical policies (as pointed out on p. 85).

AH.K=(DH.KxEDDSF.K)-EECHR.KxS.K 20, A

AH - Approved hires (staff)
DH - Desired hires (staff
EDDSF- Effect of delivery delay on the support from funder (dim. less)
EECHR- Effective economic constraint on hiring (dim. less)
S - Staff (staff)

DH.K=(ALR.KxPTME)+DXS.KxS.K 21, A

DH - Desired hires (staff)
ALR - Average leave rate (staff/week)
PTME - Hiring time (weeks)
DXS - Desired expansion of staff (dim. less)
S - Staff (staff)

ALR.K=SMOOTH(LR.JK,LMPT) 22, A

ALR - Average leave rate (staff/week)
LR - Leave rate (staff/week)
LMPT - Management's long term perception time (weeks)

The first factor in equation 20 determining the approved hires is desired hires DH. This is what the ISS management considers needed to give a satisfactory service, and it corresponds to a request for funding.

The desired hires DH is formulated in equation 21 as the sum of a compensation for staff that has left and a desired increase in staff which depends on the delivery delay situation perceived by management. Management knows the average leave rate ALR, and it also knows how long it will take to fill positions: the hiring time PTME. Therefore it is necessary to multiply the average leave rate with the hiring time to compensate for leaving staff. ALRxPTME then represents management's estimate of the number of staff leaving. The desired expansion of staff DXS which is explained below is given as a percentage so DXSxS gives the actual number of staff desired. The hiring time PTME was defined in equation 11.1 as 26 weeks.

The average leave rate ALR is defined in equation 22 as a smooth of the actual leave rate LR. The smoothing time is equal to the management's long term perception time LMPT which was given in equation 16.1 as 26 weeks.

In equation 23 the desired expansion of staff DXS is defined. DXS is a table function the value of which depends on the delivery delay situation perceived by management, formulated as the ratio between the long term delivery delay perceived by management LDDPM and the long term delivery delay norm held by management LDDNM. The table function defining DXS is given in Figure 11.

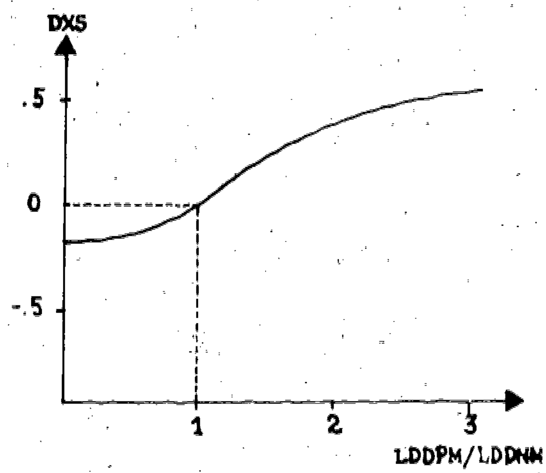

Figure 11
Desired expansion of staff.

The formulation of the desired expansion of staff DXS is fairly conservative as can be seen in Figure 11. When the perceived delivery delay is twice as long as the norm, which is an indication of insufficient number of staff, the increase requested by management is assumed to be 35%. It is also assumed that management never requests more than an increase of 50%. When the delivery delay perceived by management is shorter than the norm, i.e. when LDDPM/LDDNM is less than one, it is assumed that the ISS management makes "responsible" requests for funding and accepts a decrease in the number of staff.

```
DXS.K=TABLE(TDXS,LDDPM.K/LDDNM,0,3,0.5)          23, A
LDDNM=0.5                                        23.1, C
TDXS=-.2/-.15/0/.2/.35/.45/.5                    23.2, T
```

DXS - Desired expansion of staff (dim. less)
LDDPM- Long term delivery delay perceived by management (weeks)
LDDNM- Long term delivery delay norm held by management (weeks)

The conservatism in the decision regarding DXS is also manifested by the choice of the long term delivery delay norm held by management LDDNM which is set to half a week - the same as the delivery delay norm held by the market DDN. LDDNM is specified in equation 23.1.

In equation 23 and 23.2 the desired expansion of staff is defined. Together these two equations give the following value pairs:

DXS	-20%	-15%	0	20%	35%	45%	50%
LDDPM/LDDNM	0.00	0.50	1.00	1.50	2.00	2.50	3.00

Returning to equation 20 where the approved hires is defined we see that the desired hires will not automatically become approved - the funder's willingness to support the service, represented as the effect from delivery delay on the support from funder, EDDSF, will also have an influence. We have pointed out that an ISS has fairly established procedures for evaluative feedback (see page 26) which constitute a vehicle for the users to practice the "voice" option as a response to declining quality of the service. If a bad delivery delay situation is sustained for a long period of time, i.e. if a long time average of the delivery delay is longer than the norm, users will be dissatisfied and the funder will consider using his resources on other functions than the ISS. The delivery delay perceived by funder, DDPF, is a long term average of the delivery delay perceived by users - recall from equation 15 that the funder's perception time is 40 weeks. Since the users perception time is 13 weeks (equation 13) this means that the funder reacts to approximately the average value for the preceding year.

The effect of delivery delay on the support from funder, EDDSF, is illustrated in Figure 12.

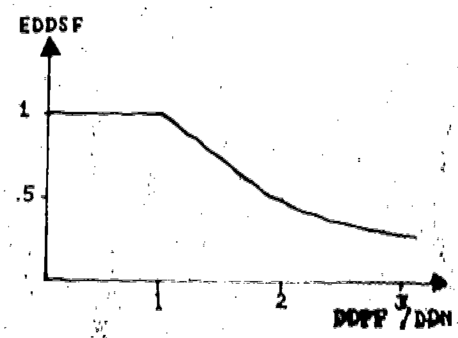

Figure 12

The effect from delivery delay on the support from funder.

When the long term delivery delay is equal to the norm or better, i.e. when DDPF/DDN is less than or equal to one, the funder is supportive and accepts the desired hires requested by management. In Figure 12 this is represented by making the value of EDDSF equal to one for this case. When DDPF/DDN is greater than one the funder will show his scepticism by reducing the requests for funding. It is assumed that this reduction is linearly dependent on the delivery delay situation but that there is a lower bound for EDDSF.

```
EDDSF.K=TABHL(TEDDSF,DDPF.K/DDN,1,3,0.5)          24, A
TEDDSF=1/.75/.50/.40/.35                           24.1, T

      EDDSF- Effect of delivery delay on
             the support from funder (dim. less)
      DDPF - Delivery delay perceived by funder
             (weeks)
      DDN  - Delivery delay norm (weeks)

EECHR.K=ECHR.K×EEC.K                               25, A

      EECHR- Effective economic constraint
             on hiring (dim. less)
      ECHR - Economic constraint on hiring
             (dim. less)
      EEC  - Enforcement of economic constraint
             (dim. less)
```

The TABHL function in equation 24 together with the table in equation 24.1 produce the following value pairs:

EDDSF	1.00	0.75	0.50	0.40	0.35
DDPF/DDN	1.00	1.50	2.00	2.50	3.00

For values of DDPF/DDN less than one and greater than three the first and last values of EDDSF apply (see p. 105).

The last determinant of approved hires AH in equation 20 is the effect of the economic constraint on hiring. From the beginning it has been common to charge the users of ISSs for the service, and a recent discussion about developments in the field of scientific and technical information dissemination indicates that economic considerations are becoming increasingly important (Schwarz, 1976, p. 9 ff.). De Gennaro (1975) provides a discussion of the developments that have led to this situation. Regarding user fees for computer-based bibiliographic search services "most libraries have found it necessary to recover at least some costs in this manner" (Gardner et al., p. 4).

The effective economic constraint on hiring is defined in equation 25 as the product of two terms: the economic constraint on hiring, ECHR, and the enforcement of the economic constraint, EEC. The latter factor is explained further below and in equation 27; it represents the effect that the funder is willing to refrain from enforcing the economic constraint, especially during the start-up period of the service.

```
ECHR.K=TABHL(TECHR,REVGL/REVIX.K,1,1.5,0.1)      26, A
TECHR=0/.08/.15/.20/.23/.25                      26.1, T
REVGL=8                                          26.2, C

     ECHR - Economic constraint on hiring
            (dim. less)
     REVGL- Revenue goal (queries/week/staff)
     REVIX- Revenue index (dim. less)
```

The economic constraint on hiring, ECHR, is a function of the ratio between the revenue goal REVGL and the revenue index REVIX, and is defined by the TABHL function in equation 26 and the table in equation 26.1. If the revenue index is greater than the revenue goal, i.e. REVGL/REVIX is less than one, then there is no economic constraint on hiring and ECHR is zero.

If the revenue goal is higher than what is actually achieved then economic concerns on part of the funder will result in cut-backs in the number of approved hires and eventually in the number of staff. It is assumed that the funder does not make a sudden decision to discontinue the service totally but that there is a maximum cut-back of 25% of the staff, and that he will approach this limit gradually as shown in Figure 13.

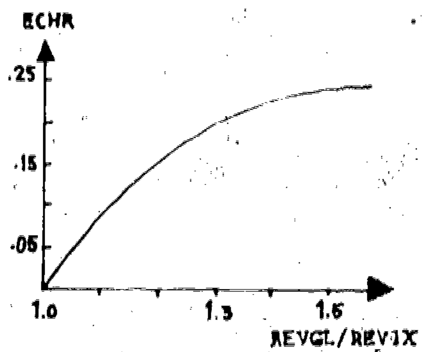

Figure 13

The economic constraint on hiring.

The value pairs generated by equations 26 and 26.1 are:

ECHR	.00	.08	.15	.20	.23	.25
REVGL/REVIX	1.0	1.1	1.2	1.3	1.4	1.5

As we have said above the ISS is expected to recover some of its costs. We have chosen to express this revenue goal as an expected number of queries per week per staff. The revenue goal REVGL is set to 8 queries per week per staff (equation 26.2). Revenue goals are mostly not expressed thus explicity but the economic performance of an ISS is typically judged on a more aggregate level, e.g. on the basis of annual reports. The realism of the chosen revenue goal can be inferred from the actual situation at NASIC/MIT (Pensyl, 1977): for the period June 1976 to May 1977 the average number of search requests per week and staff was 7.95.[+] This resulted in an income practically equal to the computation and operating expenses - not explicitly stated as a goal, but a situation that is becoming a norm for ISSs:

> "A common pattern is that the library absorbs the indirect costs such as the cost of the terminal and staff operators' time, but asks the user to pay the direct costs including computer time, printing, and communication charges." (De Gennaro, 1975).

The second factor affecting the effective economic constraint on hiring, EECHR, in equation 25 is the enforcement of the economic constraint EEC. For a reasonable start-up period it is assumed that the funder is willing to accept that the number of queries per week and staff will not be equal to his goal; he guarantees a budget for the ISS operations. In the simulation model this is represented as a discretionary fund which is depleted by a certain amount weekly, this amount being what the funder thinks "should" be recovered, unless the volume of business is at the revenue goal, in which case the fund will be left intact. It is also possible that the fund will be

+) The figure given in the report is 3.65 searches per day and "searcher". In this case searches are counted once for each data base accessed and the number of such accesses is about 2.3 per user, thus the number of queries per week (with our definitions) is: $(3.65/2.3)\times 5 = 7.93$.

built up after a decline by achieving a volume of business that is higher than the revenue goal. The enforcement of the economic constraint EEC is a function of what is left in the discretionary fund DF relative to the initial amount NSUF. The ratio DF/NSUF is then taken as a measure of the economic viability of the ISS operation. The relationship between this measure and EEC is given in Figure 14.

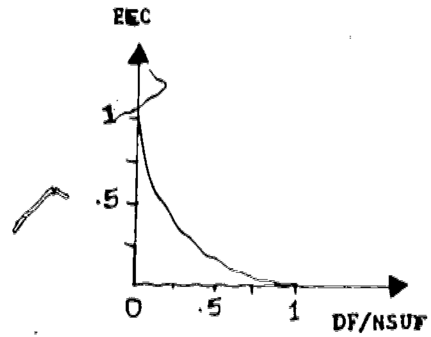

Figure 14
The enforcement of the economic constraint.

When the ratio DF/NSUF is one or greater then EEC is zero; in this case the ISS operation brings in the expected amount of money and the economic constraint on hiring is not enforced. As the ratio becomes less, which means that the discretionary fund is being depleted the funder becomes increasingly concerned - in Figure 14 this is represented by an increasing (negative) slope for the function. If the discretionary fund is used up the economic constraint will be enforced fully, i.e. EEC will have the value one.

The enforcement of the economic constraint EEC is defined in equation 27 as a TABHL function.

```
EEC.K=TABHL(TEEC,DF.K/NSUF,0,1,0.25)          27, A
TEEC=1/.45/.20/.07/0                          27.1, T

      EEC  - Enforcement of economic constraint
             (dim. less)
      DF.  - Discretionary funds (dollars)
      NSUF - Initial start-up fund (dollars)
```

Together with the table in equation 27.1 the TABHL function renders the following value pairs:

EEC	1.00	0.45	0.20	0.07	0.00
DF/NSUF	0.00	0.25	0.50	0.75	1.00

To keep the model simple we have chosen not to include equations describing the cost accounting. Cost data are generally difficult to obtain. One reason is that sometimes the ISS together with the hosting library is embedded within a larger organizational framework (see p. 17 and Zais, 1977, p. 93), another is that the charging scheme from the service suppliers can be very complex.

We need, however, some measure of the economic viability of the ISS, and as mentioned above we have made a formulation with a discretionary fund DF. Equation 28 is the level equation defining the discretionary fund. It is increased by the income DIN, by which we mean income in excess of the charges passed on to the user. The fund is depleted by the reduction in discretionary funds DUT, which represents what the funder thinks "should" be flowing in to meet operating expenses.

```
DF.K=DF.J+(DT)x(DIN.JK-DUT.JK)                         28, L
DF=NSUF                                                28.1, N
NSUF=15000                                             28.2, C

     DF   - Discretionary funds (dollars)
     DIN  - Income (dollars/week)
     DUT  - Reduction in discretionary funds
            (dollars/week)
     NSUF - Initial start-up fund (dollars)

DIN.KL=AR.JKxRECF                                      29, R
RECF=10                                                29.1, C

     DIN  - Income (dollars/week)
     AR   - Answer rate (queries/week)
     RECF - Recovery factor (dollars/query)

DUT.KL=S.KxREVGLxRECF                                  30, R

     DUT  - Reduction in discretionary funds
            (dollars/week)
     S    - Staff (staff)
     REVGL- Revenue goal (queries/week/staff)
     RECF - Recovery factor (dollars/query)
```

Equation 28.1 is an initial value equation which says that the initial discretionary fund is equal to the constant NSUF which in equation 28.2 is given as \$ 15 000. The SDC study (Wanger et al., 1976, p. 153) gives as a typical case that the initial allocation for the ISS budget was sufficient for the first year of the on-line operation, and that the cost estimates had been close to the actual outcome. Here we assume an estimated cost per query of \$ 10 (see below) and with a revenue goal of 8 queries/week/staff and a staff of three the initial allocation NSUF will cover about a year and a quarter. This is the time is would take before the funder would consider the ISS, totally "bankrupt" if no money at all was recovered. However, his economic concern would be aroused earlier and he would start to enforce the economic constraint on hiring.

Equation 29 is the rate equation describing the income to the discretionary fund, DIN, as the product of the answer rate AR and the recovery factor RECF, which is like a surcharge the users pay in addition to computation costs. RECF is given in equation 29.1 as $ 10 per query (see below for discussion). This means that the ISS will have to charge the users about $ 30-$ 40 per query: the average cost per query at NASIC/MIT is about $ 35 (2.3 NASIC searches times the average total cost of $ 15.75 per search (Pensyl, 1977), the SDC study (Wanger et al., 1976, p. A-8) gives an average cost per search of $ 23.83 (median $ 17.16) but does not reveal how many such searches are made for one query.

Equation 30 is the rate equation describing the reduction in discretionary funds, DUT, and represents the expected cost, which occurs in addition to what the user pays for computing costs, at a volume of business equal to revenue goal REVGL. The total reduction will then be (S(staff)xREVGL(queries/week/staff)xRECF($/query)), with the dimension ($/week).

In practice the funders estimated cost is often not explicitly stated as we have done here, so the surcharge will have to be estimated by management. Here we have assumed that the same estimate, RECF, is used by both. At the NASIC/MIT service the income less computing expenses, i.e. the recovery factor, is $ 6.44 per query (2.3 NASIC searches times $ 2.80 (Pensyl, 1977)), and the operating expenses, calculated analogously, are $ 7.19 per query. Operating expenses include such things as materials, postage, telephone, but there is no standard way of defining these costs: here we have for simplicity assumed $ 10 per query. The equations relating to the economics of the ISS should be regarded as a simplified representation of the budgeting process.

The resource allocation decision is described in equations 31-37. It is in the nature of a service like an ISS to have a reactive resource allocation policy: management tries to spend some resources on marketing but when queries come in they have to be answered. Since it is common to have the users make appointments with the staff in advance, and since marketing activities involve other commitments, e.g. rental of space for demonstrations, changes in the allocation cannot be effective immediately. The allocation change time ACT is, however, assumed to be relatively short: equation 31.1 gives the value two weeks.

In equation 31 the allocation of staff to production, ASP, is defined as a SMOOTH (see page 105) of the decided allocation of staff to production. A smoothing time of two weeks means that this is the time over which the change will take place.

```
ASP.K=SMOOTH(DAP.K,ACT)                              31, A
ACT=2                                                31.1, C

      ASP  - Allocation of staff to production
             (staff)
      DAP  - Decided allocation of staff to
             production (staff)
      ACT  - Allocation change time (weeks)

DAP.K=MIN(IAP.K,ISP.K)                               32, A

      DAP  - Decided allocation of staff to
             production (staff)
      IAP  - Indicated balanced allocation of
             staff to production (staff)
      ISP  - Staff needed for production to
             keep delivery delay norm (staff)
```

```
ISP.K=Q.K/(SPQRxDDNM)                              33, A
DDNM=0.5                                           33.1, C

      ISP  - Staff nedded for production to
             keep delivery delay norm (staff)
      Q    - Query backlog (queries)
      SPQR - Staff productivity (queries/week/
             staff)
      DDNM - Delivery delay norm held by manage-
             ment (weeks)
```

Equation 32 defines the desired allocation of staff to production, DAP, as the minimum of two variables: the indicated balanced allocation of staff to production, IAP, and the staff needed for production to keep the delivery delay norm, ISP.

DAP is the actual decision about how much staff should be allocated to production. The ISS management allocates enough staff to keep the delivery delay at the norm, until there is a conflict from the pressure to allocate resources to marketing and assistance - it is not possible to allocate 100% of the staff to searching since some assistance will have to be provided.

In practice it can happen that it is not possible to allocate the necessary resources to production immediately; Hjerppe (1975, pp. 125-126) reports:

> "... unprocessed queries piled up quite rapidly, especially if the system had a serious break-down. The situation this fall, 1974, has been that we have for at least two months had a queue of 10-20 queries waiting, and this backlog is very hard to eliminate as long as the queries keep coming at a regular pace, which is what we in other circumstances would want them to do."

In equation 33 the number of staff needed to keep the delivery delay norm, ISP, is calculated. ISP depends on how big the query backlog Q is. By dividing Q by the staff productivity (queries/staff/week) multiplied with the delivery delay norm (weeks) we get the needed number of staff.

The delivery delay norm held by management DDNM is assumed to be the same as the norm held by the market, half a week (see p. 122).

```
ISM.K=U.KxANEEDxNDBIAS                         34, A
NDBIAS=1                                       34.1, C

      ISM   - Staff needed for marketing (staff)
      U     - Users (users)
      ANEED- Assistance needed per user (staff/
             week/user)
      NDBIAS- Bias in recognizing need for
              marketing and assistance (dim.
              less)
```

The pressure to allocate staff to assistance and marketing is recognized in equation 34 which defines the staff needed for marketing, ISM. ISM is defined as the number of users U times the need for asstistance ANEED in terms of staff per user. There is also bias factor NDBIAS which represents the ability of the ISS management to recognize the need for assistance properly. For the standard run it is assumed that management makes a correct assessment so NDBIAS is equal to one in equation 34.1.

It might not be possible to meet the different needs for staff: the staff needed to keep the delivery delay norm, ISP (equation 33) and the staff needed for marketing, ISM (equation 34) might add up to more than the total staff. One way of resolving this conflict is to make a balanced allocation so that the allocation to each of the two functions is made according to the relative size of the need for that function, i.e. if the total need (ISP + ISM) is y, and ISP itself is x, then x/y of the staff would be allocated to production. This formulation is given in equation 35.

IFP.K=ISP.K/(ISP.K+ISM.K) 35, A

IFP - Indicated balanced fractional allocation of staff to production (fraction)
ISP - Staff needed for production to keep delivery delay norm (staff)
ISM - Staff needed for rketing (staff)

IAP.K=IFP.KxS.K 36, A

IAP - Indicated balanced allocation of staff to production (staff)
IFP - Indicated balanced fractional allocation of staff to production (fraction)
S - Staff (staff)

The balanced allocation formula reflects the real life situation that although managers try to keep a fast service they are aware of the necessity of assistance and marketing; one of the conclusions from the first phase of the NASIC/MIT service, for example, was that "promotional efforts need to be very intense" (Benenfeld et al., 1975, p. 1-2).

In equation 36 the indicated balanced fractional allocation of staff to production, IFP, is used to calculate the indicated balanced allocation of staff to production, IAP, expressed in absolute numbers, by multiplication with the total number of staff available S. IAP is then one of the factors considered when the allocation decision is made in equation 32 (see p. 145).

The staff resources not allocated to production are available for marketing and assistance activities, as described in equation 37. This equation simply states that the allocation of staff to marketing and assistance, ASM, is equal to the total staff S less what has been allocated to production, ASP.

ASM.K=S.K-ASP.K 37, A

ASM - Allocation of staff to marketing and assistance (staff)
S - Staff (staff)
ASP - Allocation of staff to production (staff)

Equations 40-47 define performance and operational measures which can help in assessing the "results" of different simulation runs. They will not be described further, but they are listed in the next section.

The performance measure used to assess the revenue situation of the ISS, which affects the economic constraint on hiring (in equation 26), is the revenue index REVIX described in equation 48. It is the ratio of the average query rate AVQR, defined in equation 49, and the average number of staff, defined in equation 50. The smoothing time STRA for the components of REVIX is assumed to be equal to the other administrative delays, hiring time PTME in equation 11.1 and LMPT in equation 16.1, i.e. 26 weeks as specified in equation 50.1.

REVIX.K=AVQR.K/AVS.K 48, A

REVIX- Revenue index (dim. less)
AVQR - Average query rate (queries/week)
AVS - Average staff (staff)

AVQR.K=SMOOTH(QR.JK,STRA) 49, A

AVQR - Average query rate (queries/week)
QR - Query rate (queries/week)
STRA - Smoothing time for revenue assessment (weeks)

AVS.K=SMOOTH(S.K,STRA) 50, A
STRA=26 50.1, C

AVS - Average staff (staff)
S - Staff (staff)
STRA - Smoothing time for revenue assessment (weeks)

This completes the description of the model equations. To run the model initial values for Q, S, and U and control "cards" are needed, these are also given in the following section.

III. MODEL LISTINGS

DOCUMENTOR listing

```
Q.K=Q.J+(DT)*(QR.JK-AR.JK)                                          1, L
Q=QN                                                                1.1, N
     Q        - QUERY BACKLOG (QUERIES)
     QR       - QUERY RATE (QUERIES/WEEK)
     AR       - ANSWER RATE (QUERIES/WEEK)
     QN       - INITIAL NO OF QUERIES

QR.KL=U.K*PQ.K                                                      2, R
     QR       - QUERY RATE (QUERIES/WEEK)
     U        - USERS (USERS)
     PQ       - PROPENSITY TO QUERY (QUERIES/WEEK/USER)

AR.KL=ASP.K*SPQR*EQAAR.K                                            3, R
     AR       - ANSWER RATE (QUERIES/WEEK)
     ASP      - ALLOCATION OF STAFF TO PRODUCTION (STAFF)
     SPQR     - STAFF PRODUCTIVITY (QUERIES/WEEK/STAFF)
     EQAAR    - EFFECT OF QUERY AVAILABILITY ON ANSWER RATE
                  (DIM. LESS)

EQAAR.K=TABHL(TEQAAR,Q.K,0,0.02,0.005)                              4, A
TEQAAR=0/.1/.5/.9/1                                                 4.1, T
SPQR=10                                                             4.2, C
     EQAAR    - EFFECT OF QUERY AVAILABILITY ON ANSWER RATE
                  (DIM. LESS)
     Q        - QUERY BACKLOG (QUERIES)
     SPQR     - STAFF PRODUCTIVITY (QUERIES/WEEK/STAFF)

U.K=U.J+(DT)*(ER.JK-TR.JK)                                          5, L
U=UN                                                                5.1, N
     U        - USERS (USERS)
     ER       - ENTRY RATE (USERS/WEEK)
     TR       - TERMINATION RATE (USERS/WEEK)
     UN       - INITIAL NO. OF USERS

TR.KL=U.K*TRN                                                       6, R
TRN=0.02                                                            6.1, C
     TR       - TERMINATION RATE (USERS/WEEK)
     U        - USERS (USERS)
     TRN      - TERMINATION RATE NORMAL(FRACTION/WEEK)

ER.KL=(U.K)(UGN)(EMAER.K)(EDDER.K)(EMPER.K)                         7, R
UGN=0.0374                                                          7.1, C
     ER       - ENTRY RATE (USERS/WEEK)
     U        - USERS (USERS)
     UGN      - USER GROWTH RATE NORMAL (FRACTION/WEEK)
     EMAER    - EFFECT OF MARKETING AND ASSISTANCE ON ENTRY
                  RATE (DIM. LESS)
     EDDER    - EFFECT OF DELIVERY DELAY ON ENTRY RATE
                  (DIM. LESS)
     EMPER    - EFFECT OF MARKET PENETRATION ON ENTRY RATE
                  (DIM. LESS)
```

```
EMPER.K=TABLE(TEMPER,U.K/PU,0,1,0.2)                          8, A
TEMPER=1/1.05/1.1/1.05/.80/0                                  8.1, T
PU=2000                                                       8.2, C
    EMPER   - EFFECT OF MARKET PENETRATION ON ENTRY RATE
                (DIM. LESS)
    U       - USERS (USERS)
    PU      - POTENTIAL MARKET (USERS)

S.K=S.J+(DT)*(HR.JK-LR.JK)                                    9, L
S=SN                                                          9.1, N
    S       - STAFF (STAFF)
    HR      - HIRING RATE (STAFF/WEEK)
    LR      - LEAVE RATE (STAFF/WEEK)
    SN      - INITIAL NO. OF STAFF

LR.KL=S.K/TOJ                                                 10, R
TOJ=200                                                       10.1, C
    LR      - LEAVE RATE (STAFF/WEEK)
    S       - STAFF (STAFF)
    TOJ     - TIME ON JOB (WEEKS)

HR.KL=AH.K/PTME                                               11, R
PTME=26                                                       11.1, C
    HR      - HIRING RATE (STAFF/WEEK)
    AH      - APPROVED HIRES (STAFF)
    PTME    - HIRING TIME (WEEKS)

DELIVERY DELAY ETC.

DIX.K=Q.K/AR.JK                                               12, A
    DIX     - DELIVERY DELAY INDICATED (WEEKS)
    Q       - QUERY BACKLOG (QUERIES)
    AR      - ANSWER RATE (QUERIES/WEEK)

DDPU.K=SMOOTH(DIX.K,UPT)                                      13, A
UPT=13                                                        13.1, C
    DDPU    - DELIVERY DELAY PERCEIVED BY USERS (DIM.
                LESS)
    DIX     - DELIVERY DELAY INDICATED (WEEKS)
    UPT     - USERS' PERCEPTION TIME (WEEKS)

DDPP.K=SMOOTH(DDPU.K,PPT)                                     14, A
PPT=26                                                        14.1, C
    DDPP    - DELIVERY DELAY PERCEIVED BY POTENTIAL USERS
                (WEEKS)
    DDPU    - DELIVERY DELAY PERCEIVED BY USERS (WEEKS)

    PPT     - POTENTIAL USERS' PERCEPTION TIME (WEEKS)

DDPF.K=SMOOTH(DDPU.K,FPT)                                     15, A
FPT=40                                                        15.1, C
    DDPF    - DELIVERY DELAY PERCEIVED BY FUNDER (WEEKS)
    DDPU    - DELIVERY DELAY PERCEIVED BY USERS (WEEKS)

    FPT     - FUNDER'S PERCEPTION TIME (WEEKS)
```

```
LDDPM.K=SMOOTH(DIX.K,LMPT)                                  16, A
LMPT=26                                                     16.1, C
    LDDPM   - LONG TERM DELIVERY DELAY PERCEIVED BY
                MANAGEMENT (WEEKS)
    DIX     - DELIVERY DELAY INDICATED (WEEKS)
    LMPT    - MANAGEMENT'S LONG TERM PERCEPTION TIME
                (WEEKS)
```

EFFECTS OF DD

```
PQ.K=PQN*EDDPQ.K                                            17, A
    PQ      - PROPENSITY TO QUERY (QUERIES/WEEK/USER)
    PQN     - NORMAL PROPENSITY TO QUERY (QUERIES/WEEK/
                USER)
    EDDPQ   - EFFECT OF DELIVERY DELAY ON THE PROPENSITY
                TO QUERY (DIM. LESS)

EDDPQ.K=TABLE(TEDDPQ,DDPU.K/DDN,0,3,0.5)                    18, A
TEDDPQ=1.5/1.25/1/.8/.65/.57/.5                             18.1, T
    EDDPQ   - EFFECT OF DELIVERY DELAY ON THE PROPENSITY
                TO QUERY (DIM. LESS)
    DDPU    - DELIVERY DELAY PERCEIVED BY USERS (WEEKS)

    DDN     - DELIVERY DELAY NORM (WEEKS)

EDDER.K=TABLE(TEDDER,DDPP.K/DDN,0,3,0.5)                    19, A
TEDDER=1.6/1.47/1/.47/.3/.3/.3                              19.1, T
    EDDER   - EFFECT OF DELIVERY DELAY ON ENTRY RATE
                (DIM. LESS)
    DDPP    - DELIVERY DELAY PERCEIVED BY POTENTIAL USERS
                (WEEKS)
    DDN     - DELIVERY DELAY NORM (WEEKS)
```

LONG TERM DECISIONS

```
AH.K=(DH.K*EDDSF.K)-EECHR.K*S.K                             20, A
    AH      - APPROVED HIRES (STAFF)
    DH      - DESIRED HIRES (STAFF)
    EDDSF   - EFFECT OF DELIVERY DELAY ON THE SUPPORT
                FROM FUNDER (DIM. LESS)
    EECHR   - EFFECTIVE ECONOMIC CONSTRAINT ON HIRING
                (DIM. LESS)
    S       - STAFF (STAFF)

DH.K=(ALR.K*PTME)+DXS.K*S.K                                 21, A
    DH      - DESIRED HIRES (STAFF)
    ALR     - AVERAGE LEAVE RATE (STAFF/WEEK)
    PTME    - HIRING TIME (WEEKS)
    DXS     - DESIRED EXPANSION OF STAFF(DIM. LESS)
    S       - STAFF (STAFF)

ALR.K=SMOOTH(LR.JK,LMPT)                                    22, A
    ALR     - AVERAGE LEAVE RATE (STAFF/WEEK)
    LR      - LEAVE RATE (STAFF/WEEK)
    LMPT    - MANAGEMENT'S LONG TERM PERCEPTION TIME
                (WEEKS)
```

```
DXS.K=TABLE(TDXS,LDDPM.K/LDDNM,0,3,0.5)                    23, A
LDDNM=0.5                                                  23.1, C
TDXS=-.2/-.15/0/.2/.35/.45/.5                              23.2, T
    DXS    - DESIRED EXPANSION OF STAFF(DIM. LESS)
    LDDPM  - LONG TERM DELIVERY DELAY PERCEIVED BY
               MANAGEMENT (WEEKS)
    LDDNM  - LONG TERM DELIVERY DELAY NORM HELD BY
               MANAGEMENT (WEEKS)

EDDSF.K=TABHL(TEDDSF,DDPF.K/DDN,1,3,0.5)                   24, A
TEDDSF=1/.75/.50/.40/.35                                   24.1, T
    EDDSF  - EFFECT OF DELIVERY DELAY ON THE SUPPORT
               FROM FUNDER (DIM. LESS)
    DDPF   - DELIVERY DELAY PERCEIVED BY FUNDER (WEEKS)
    DDN    - DELIVERY DELAY NORM (WEEKS)

EECHR.K=ECHR.K*EEC.K                                       25, A
    EECHR  - EFFECTIVE ECONOMIC CONSTRAINT ON HIRING
               (DIM. LESS)
    ECHR   - ECONOMIC CONSTRAINT ON HIRING (DIM. LESS)
    EEC    - ENFORCEMENT OF ECONOMIC CONSTRAINT (DIM.
               LESS)

ECHR.K=TABHL(TECHR,REVGL/REVIX.K,1,1.5,0.1)                26, A
TECHR=0/.08/.15/.20/.23/.25                                26.1, T
REVGL=8                                                    26.2, C
    ECHR   - ECONOMIC CONSTRAINT ON HIRING (DIM. LESS)
    REVGL  - REVENUE GOAL (QUERIES/WEEK/STAFF)
    REVIX  - REVENUE INDEX (DIM. LESS)

EEC.K=TABHL(TEEC,DF.K/NSUF,0,1,0.25)                       27, A
TEEC=1/.45/.20/.07/0                                       27.1, T
    EEC    - ENFORCEMENT OF ECONOMIC CONSTRAINT (DIM.
               LESS)
    DF     - DISCRETIONARY FUNDS (DOLLARS)
    NSUF   - INITIAL START-UP FUND (DOLLARS)

DF.K=DF.J+(DT)*(DIN.JK-DUT.JK)                             28, L
DF=NSUF                                                    28.1, N
NSUF=15000                                                 28.2, C
    DF     - DISCRETIONARY FUNDS (DOLLARS)
    DIN    - INCOME (DOLLARS/WEEK)
    DUT    - REDUCTION IN DISCRETIONARY FUNDS (DOLLARS/WEEK)
    NSUF   - INITIAL START-UP FUND (DOLLARS)

DIN.KL=AR.JK*RECF                                          29, R
RECF=10                                                    29.1, C
    DIN    - INCOME (DOLLARS/WEEK)
    AR     - ANSWER RATE (QUERIES/WEEK)
    RECF   - RECOVERY FACTOR (DOLLARS/QUERY)

DUT.KL=S.K*REVGL*RECF                                      30, R
    DUT    - REDUCTION IN DISCRETIONARY FUNDS (DOLLARS/WEEK)
    S      - STAFF (STAFF)
    REVGL  - REVENUE GOAL (QUERIES/WEEK/STAFF)
    RECF   - RECOVERY FACTOR (DOLLARS/QUERY)
```

ALLOCATION OF STAFF

```
ASP.K=SMOOTH(DAP.K,ACT)                                      31, A
ACT=2                                                        31.1, C
    ASP    - ALLOCATION OF STAFF TO PRODUCTION (STAFF)
    DAP    - DECIDED ALLOCATION OF STAFF TO PRODUCTION
               (STAFF)
    ACT    - ALLOCATION CHANGE TIME (WEEKS)

DAP.K=MIN(IAP.K,ISP.K)                                       32, A
    DAP    - DECIDED ALLOCATION OF STAFF TO PRODUCTION
               (STAFF)
    IAP    - INDICATED BALANCED ALLOCATION OF STAFF TO
               PRODUCTION (STAFF)
    ISP    - STAFF NEEDED FOR PRODUCTION TO KEEP
               DELIVERY DELAY NORM (STAFF)

ISP.K=Q.K/(SPQR*DDNM)                                        33, A
DDNM=0.5                                                     33.1, C
    ISP    - STAFF NEEDED FOR PRODUCTION TO KEEP
               DELIVERY DELAY NORM (STAFF)
    Q      - QUERY BACKLOG (QUERIES)
    SPQR   - STAFF PRODUCTIVITY (QUERIES/WEEK/STAFF)
    DDNM   - DELIVERY DELAY NORM HELD BY MANAGEMANT
               (WEEKS)

ISM.K=U.K*ANEED*NDBIAS                                       34, A
NDBIAS=1                                                     34.1, C
    ISM    - STAFF NEEDED FOR MARKETING (STAFF)
    U      - USERS (USERS)
    ANEED  - ASSISTANCE NEEDED PER USER (STAFF/WEEK/
               USER)
    NDBIAS - BIAS IN RECOGNIZING NEED FOR MARKETING AND
               ASSISTANCE (DIM. LESS)

IFP.K=ISP.K/(ISP.K+ISM.K)                                    35, A
    IFP    - INDICATED BALANCED FRACTIONAL ALLOCATION OF
               STAFF TO PRODUCTION (FRACTION)
    ISP    - STAFF NEEDED FOR PRODUCTION TO KEEP
               DELIVERY DELAY NORM (STAFF)
    ISM    - STAFF NEEDED FOR MARKETING (STAFF)

IAP.K=IFP.K*S.K                                              36, A
    IAP    - INDICATED BALANCED ALLOCATION OF STAFF TO
               PRODUCTION (STAFF)
    IFP    - INDICATED BALANCED FRACTIONAL ALLOCATION OF
               STAFF TO PRODUCTION (FRACTION)
    S      - STAFF (STAFF)

ASM.K=S.K-ASP.K                                              37, A
    ASM    - ALLOCATION OF STAFF TO MARKETING AND
               ASSISTANCE (STAFF)
    S      - STAFF (STAFF)
    ASP    - ALLOCATION OF STAFF TO PRODUCTION (STAFF)
```

EFFECT OF MARKETING

```
ASTND.K=U.K*ANEED                                          38, A
ANEED=0.001                                                38.1, C
    ASTND  - ASSISTANCE NEEDED (STAFF/WEEK)
    U      - USERS (USERS)
    ANEED  - ASSISTANCE NEEDED PER USER (STAFF/WEEK/
               USER)

EMAER.K=TABLE(TEMAER,ASTND.K/ASM.K,0,3,0.25)               39, A
TEMAER=2/1.55/1.3/1.1/1/.81/.7/.62/.56/.5/.45/.42/         39.1, T
  .38
DDN=0.5                                                    39.2, C
PQN=0.035                                                  39.3, C
    EMAER  - EFFECT OF MARKETING AND ASSISTANCE ON ENTRY
               RATE (DIM. LESS)
    ASTND  - ASSISTANCE NEEDED (STAFF/WEEK)
    ASM    - ALLOCATION OF STAFF TO MARKETING AND
               ASSISTANCE (STAFF)
    DDN    - DELIVERY DELAY NORM (WEEKS)
    PQN    - NORMAL PROPENSITY TO QUERY (QUERIES/WEEK/
               USER)
```

PERFORMANCE AND OPERATIONAL MEASURES

```
SAR.K=SAR.J+(DT)*(AR.JK)                                   40, L
SAR=NSAR                                                   40.1, N
NSAR=0                                                     40.2, C
    SAR    - TOTAL NO. OF ANSWERED QUERIES (QUERIES)
    AR     - ANSWER RATE (QUERIES/WEEK)

SER.K=SER.J+(DT)*(ER.JK)                                   41, L
SER=NSER                                                   41.1, N
NSER=0                                                     41.2, C
    SER    - TOTAL NO. OF USERS (USERS)
    ER     - ENTRY RATE (USERS/WEEK)

SRVIX.K=EDDER.K*EMAER.K                                    42, A
    SRVIX  - SERVICE INDEX
    EDDER  - EFFECT OF DELIVERY DELAY ON ENTRY RATE
               (DIM. LESS)
    EMAER  - EFFECT OF MARKETING AND ASSISTANCE ON ENTRY
               RATE (DIM. LESS)

NER.K=(ER.JK-TR.JK)                                        43, A
    NER    - NET ENTRY RATE (USERS/WEEK)
    ER     - ENTRY RATE (USERS/WEEK)
    TR     - TERMINATION RATE (USERS/WEEK)

YPUG.K=(SMOOTH(NER.K,52))*(5200)/U.K                       44, A
    YPUG   - YEARLY PERCENTAGE GROWTH IN USERS
    NER    - NET ENTRY RATE (USERS/WEEK)
    U      - USERS (USERS)
```

```
QPUG.K=(SMOOTH(NER.K,12))*(1200)/U.K                            45, A
    QPUG    - QUARTERLY PERCENTAGE GROWTH IN USERS
    NER     - NET ENTRY RATE (USERS/WEEK)
    U       - USERS (USERS)

AGOWL.K=AGOWL.J+(DT)*(GWR.JK)                                   46, L
AGOWL=NAGOWL                                                    46.1, N
NAGOWL=0                                                        46.2, C
    AGOWL   - ACCUMULATED GOODWILL
    GWR     - GOODWILL RATE

GWR.KL=SRVIX.K                                                  47, R
    GWR     - GOODWILL RATE
    SRVIX   - SERVICE INDEX

REVIX.K=AVQR.K/AVS.K                                            48, A
    REVIX   - REVENUE INDEX (DIM. LESS)
    AVQR    - AVERAGE QUERY RATE (QUERIES/WEEK)
    AVS     - AVERAGE STAFF (STAFF)

AVQR.K=SMOOTH(QR.JK,STRA)                                       49, A
    AVQR    - AVERAGE QUERY RATE (QUERIES/WEEK)
    QR      - QUERY RATE (QUERIES/WEEK)
    STRA    - SMOOTHING TIME FOR REVENUE ASSESSMENT
                (WEEKS)

AVS.K=SMOOTH(S.K,STRA)                                          50, A
STRA=26                                                         50.1, C
    AVS     - AVERAGE STAFF (STAFF)
    S       - STAFF (STAFF)
    STRA    - SMOOTHING TIME FOR REVENUE ASSESSMENT
                (WEEKS)

  INITIAL CONDITIONS AND CONTROL CARDS

QN=1                                                            50.5, C
SN=3                                                            50.6, C
UN=50                                                           50.7, C
DT=.2                                                           50.8, C
TIME=NTIME                                                      50.9, N
NTIME=0                                                         51.1, C
LENGTH=0                                                        51.2, C
PLTPER=8                                                        51.3, C
    QN      - INITIAL NO OF QUERIES
    SN      - INITIAL NO. OF STAFF
    UN      - INITIAL NO. OF USERS

PLOT  U=U/Q=Q,QR=O/S=S,ASP=%/ER=E                               51.4
    U       - USERS (USERS)
    Q       - QUERY BACKLOG (QUERIES)
    QR      - QUERY RATE (QUERIES/WEEK)
    S       - STAFF (STAFF)
    ASP     - ALLOCATION OF STAFF TO PRODUCTION (STAFF)
```

```
PLOT   EDDPQ=1,EDDER=2,EMAER=3,EMPER=4(0,2)/DXS=          51.5
  X(-1,1)/EECHR=C,EDDSF=S(0,1)
    EDDPQ  - EFFECT OF DELIVERY DELAY ON THE PROPENSITY
               TO QUERY (DIM. LESS)
    DXS    - DESIRED EXPANSION OF STAFF(DIM. LESS)
    EECHR  - EFFECTIVE ECONOMIC CONSTRAINT ON HIRING
               (DIM. LESS)
    EDDSF  - EFFECT OF DELIVERY DELAY ON THE SUPPORT
               FROM FUNDER (DIM. LESS)

PRTPER=48                                                51.7, C

PRINT     1)U/2)Q/3)S/4)QR/5)HR/6)ER                     51.8
    U      - USERS (USERS)
    Q      - QUERY BACKLOG (QUERIES)
    S      - STAFF (STAFF)
    QR     - QUERY RATE (QUERIES/WEEK)
    HR     - HIRING RATE (STAFF/WEEK)
    ER     - ENTRY RATE (USERS/WEEK)

PRINT     1)SAR/2)SER/3)EECHR/4)YPUG/5)QPUG/6)AGOWL      51.9
    SAR    - TOTAL NO. OF ANSWERED QUERIES (QUERIES)
    SER    - TOTAL NO. OF USERS (USERS)
    EECHR  - EFFECTIVE ECONOMIC CONSTRAINT ON HIRING
               (DIM. LESS)
    YPUG   - YEARLY PERCENTAGE GROWTH IN USERS
    QPUG   - QUARTERLY PERCENTAGE GROWTH IN USERS
    AGOWL  - ACCUMULATED GOODWILL
```

Definition of Variable Names

ACT	Allocation change time (week)
AGOWL	Accumulated goodwill
AH	Approved hires (staff)
ALR	Average leave rate (staff/week)
ANEED	Assistance needed per user (staff/week/user)
AR	Answer rate (queries/week)
ASM	Allocation of staff to marketing and assistance (staff)
ASP	Allocation of staff to production (staff)
ASTND	Assistance needed (staff/week)
AVQR	Average query rate (queries/week)
AVS	Average staff (staff)
DAP	Decided allocation of staff to production (staff)
DDN	Delivery delay norm (weeks)
DDNM	Delivery delay norm held by managemant (weeks)
DDPF	Delivery delay perceived by funder (weeks)
DDPP	Delivery delay perceived by potential users (weeks)
DDPU	Delivery delay perceived by users (weeks)
DF	Discretionary funds (dollars)
DH	Desired hires (staff)
DIN	Income (dollars/week)
DIX	Delivery delay indicated (weeks)
DUT	Reduction in discretionary funds (dollars/week)
DXS	Desired expansion of staff (dim. less)
ECHR	Economic constraint on hiring (dim. less)
EDDER	Effect of delivery delay on entry rate (dim. less)
EDDPQ	Effect of delivery delay on the propensity to query (dim. less)
EDDSF	Effect of delivery delay on the support from funder (dim. less)
EEC	Enforcement of economic constraint (dim. less)
EECHR	Effective economic constraint on hiring (dim. less)
EMAER	Effect of marketing and assistance on entry rate (dim. less)
EMPER	Effect of market penetration on entry rate (dim. less)
EQAAR	Effect of query availability on answer rate (dim. less)
ER	Entry rate (users/week)
FPT	Funder's perception time (weeks)

GWR	Goodwill rate
HR	Hiring rate (staff/week)
IAP	Indicated balanced allocation of staff to production (staff)
IFP	Indicated balanced fractional allocation of staff to production (fraction)
ISM	Staff needed for marketing (staff)
ISP	Staff needed for production to keep delivery delay norm (staff)
LDDNM	Long term delivery delay norm held by management (weeks)
LDDPM	Long term delivery delay perceived by management (weeks)
LMPT	Management's long term perception time (weeks)
LR	Leave rate (staff/week)
NDBIAS	Bias in recognizing need for marketing and assistance (dim. less)
NER	Net entry rate (users/week)
NSUF	Initial start-up fund (dollars)
PPT	Potential users' perception time (weeks)
PQ	Propensity to query (queries/week/users)
PQN	Normal propensity to query (queries/week/users)
PTME	Hiring time (weeks)
PU	Potential market (users)
Q	Query backlog (queries)
QN	Initial no. of queries
QPUG	Quarterly percentage growth in users
QR	Query rate (queries/week)
RECF	Recovery factor (dollars/query)
REVGL	Revenue goal (queries/week/staff)
REVIX	Revenue index (dim. less)
S	Staff (staff)
SAR	Total no. of answered queries (queries)
SER	Total no. of users (users)
SN	Initial no. of staff
SPQR	Staff productivity (queries/week/staff)
SRVIX	Service index
STRA	Smoothing time for revenue assessment (weeks)
TOJ	Time on job (weeks)
TR	Termination rate (users/week)
TRN	Termination rate normal (fraction/week)
U	Users (users)
UGN	User growth rate normal (fraction/week)

UN	Initial no. of users
UPT	Users' perception time (weeks)
YPUG	Yearly percentage growth in users

Model Index

```
NAME     NO    T  DEFINITION
   WHERE USED

ACT      31.1  C  ALLOCATION CHANGE TIME (WEEKS)
   ASP,A,31
AGOWL    46    L  ACCUMULATED GOODWILL
         46.1  N
   PRINT,51.9
AH       20    A  APPROVED HIRES (STAFF)
   HR,R,11
ALR      22    A  AVERAGE LEAVE RATE (STAFF/WEEK)
   DH,A,21
ANEED    38.1  C  ASSISTANCE NEEDED PER USER (STAFF/WEEK/
                    USER)
   ISM,A,34/ASTND,A,38
AR        3    R  ANSWER RATE (QUERIES/WEEK)
   Q,L,1/DIX,A,12/DIN,R,29/SAR,L,40
ASM      37    A  ALLOCATION OF STAFF TO MARKETING AND
                    ASSISTANCE (STAFF)
   EMAER,A,39
ASP      31    A  ALLOCATION OF STAFF TO PRODUCTION (STAFF)
   AR,R,3/ASM,A,37/PLOT,51.4
ASTND    38    A  ASSISTANCE NEEDED (STAFF/WEEK)
   EMAER,A,39
AVQR     49    A  AVERAGE QUERY RATE (QUERIES/WEEK)
   REVIX,A,48
AVS      50    A  AVERAGE STAFF (STAFF)
   REVIX,A,48
DAP      32    A  DECIDED ALLOCATION OF STAFF TO PRODUCTION
                    (STAFF)
   ASP,A,3
DDN      3        DELIVERY DELAY NORM (WEEKS)
   EDDPQ,A,      DDER,A,19/EDDSF,A,24
DDNM     33.1  C  DELIVERY DELAY NORM HELD BY MANAGEMANT
                    (WEEKS)
   ISP,A,33
DDPF     15    A  DELIVERY DELAY PERCEIVED BY FUNDER (WEEKS)
   EDDSF,A,24
DDPP     14    A  DELIVERY DELAY PERCEIVED BY POTENTIAL USERS
                    (WEEKS)
   EDDER,A,19
DDPU     13    A  DELIVERY DELAY PERCEIVED BY USERS (WEEKS)

   DDPP,A,14/DDPF,A,15/EDDPQ,A,18
DF       28    L  DISCRETIONARY FUNDS (DOLLARS)
         28.1  N
   EEC,A,27
DH       21    A  DESIRED HIRES (STAFF)
   AH,A,20
```

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DIN        29   R  INCOME (DOLLARS/WEEK)
  DF,L,28
DIX        12   A  DELIVERY DELAY INDICATED (WEEKS)
  DDPU,A,13/LDDPM,A,16
DT         50.8 C
  Q,L,1/U,L,5/S,L,9/DF,L,28/SAR,L,40/SER,L,41/AGOWL,L,46
DUT        30   R  REDUCTION IN DISCRETIONARY FUNDS (DOLLARS/WEEK)
  DF,L,28
DXS        23   A  DESIRED EXPANSION OF STAFF(DIM. LESS)
  DH,A,21/PLOT,51.5
ECHR       26   A  ECONOMIC CONSTRAINT ON HIRING (DIM. LESS)
  EECHR,A,25
EDDER      19   A  EFFECT OF DELIVERY DELAY ON ENTRY RATE
                     (DIM. LESS)
  ER,R,7/SRVIX,A,42
EDDPQ      18   A  EFFECT OF DELIVERY DELAY ON THE PROPENSITY
                     TO QUERY (DIM. LESS)
  PQ,A,17/PLOT,51.5
EDDSF      24   A  EFFECT OF DELIVERY DELAY ON THE SUPPORT
                     FROM FUNDER (DIM. LESS)
  AH,A,20/PLOT,51.5
EEC        27   A  ENFORCEMENT OF ECONOMIC CONSTRAINT (DIM.
                     LESS)
  EECHR,A,25
EECHR      25   A  EFFECTIVE ECONOMIC CONSTRAINT ON HIRING
                     (DIM. LESS)
  AH,A,20/PLOT,51.5/PRINT,51.9
EMAER      39   A  EFFECT OF MARKETING AND ASSISTANCE ON ENTRY
                     RATE (DIM. LESS)
  ER,R,7/SRVIX,A,42
EMPER       8   A  EFFECT OF MARKET PENETRATION ON ENTRY RATE
                     (DIM. LESS)
  ER,R,7
EQAAR       4   A  EFFECT OF QUERY AVAILABILITY ON ANSWER RATE
                     (DIM. LESS)
  AR,R,3
ER          7   R  ENTRY RATE (USERS/WEEK)
  U,L,5/SER,L,41/NER,A,43/PRINT,51.8
FPT        15.1 C  FUNDER'S PERCEPTION TIME (WEEKS)
  DDPF,A,15
GWR        47   R  GOODWILL RATE
  AGOWL,L,46
HR         11   R  HIRING RATE (STAFF/WEEK)
  S,L,9/PRINT,51.8
IAP        36   A  INDICATED BALANCED ALLOCATION OF STAFF TO
                     PRODUCTION (STAFF)
  DAP,A,32
IFP        35   A  INDICATED BALANCED FRACTIONAL ALLOCATION OF
                     STAFF TO PRODUCTION (FRACTION)
  IAP,A,36
ISM        34   A  STAFF NEEDED FOR MARKETING (STAFF)
  IFP,A,35
```

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ISP       33    A  STAFF NEEDED FOR PRODUCTION TO KEEP
                     DELIVERY DELAY NORM (STAFF)
   DAP,A,32/IFP,A,35
LDDNM     23.1 C  LONG TERM DELIVERY DELAY NORM HELD BY
                     MANAGEMENT (WEEKS)
   DXS,A,23
LDDPM     16    A  LONG TERM DELIVERY DELAY PERCEIVED BY
                     MANAGEMENT (WEEKS)
   DXS,A,23
LENGTH    51.2 C
LMPT      16.1 C  MANAGEMENT'S LONG TERM PERCEPTION TIME
                     (WEEKS)
   LDDPM,A,16/ALR,A,22
LR        10    R  LEAVE RATE (STAFF/WEEK)
   S,L,9/ALR,A,22
NAGOWL    46.2 C
   AGOWL,N,46.1
NDBIAS    34.1 C  BIAS IN RECOGNIZING NEED FOR MARKETING AND
                     ASSISTANCE (DIM. LESS)
   ISM,A,34
NER       43    A  NET ENTRY RATE (USERS/WEEK)
   YPUG,A,44/QPUG,A,45
NSAR      40.2 C
   SAR,N,40.1
NSER      41.2 C
   SER,N,41.1
NSUF      28.2 C  INITIAL START-UP FUND (DOLLARS)
   EEC,A,27/DF,N,28.1
NTIME     51.1 C
   TIME,N,50.9
PLTPER    51.3 C
PPT       14.1 C  POTENTIAL USERS' PERCEPTION TIME (WEEKS)
   DDPP,A,14
PQ        17    A  PROPENSITY TO QUERY (QUERIES/WEEK/USER)
   QR,R,2
PQN       39.3 C  NORMAL PROPENSITY TO QUERY (QUERIES/WEEK/
                     USER)
   PQ,A,17
PRTPER    51.7 C
PTME      11.1 C  HIRING TIME (WEEKS)
   HR,R,11/DH,A,21
PU         8.2 C  POTENTIAL MARKET (USERS)
   EMPER,A,8
Q          1    L  QUERY BACKLOG (QUERIES)
           1.1 N
   EQAAR,A,4/DIX,A,12/ISP,A,33/PLOT,51.4/PRINT,51.8
QN        50.5 C  INITIAL NO OF QUERIES
   Q,N,1.1
QPUG      45    A  QUARTERLY PERCENTAGE GROWTH IN USERS
   PRINT,51.9
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QR        2    R  QUERY RATE (QUERIES/WEEK)
   Q,L,1/AVQR,A,49/PLOT,51.4/PRINT,51.8
RECF     29.1  C  RECOVERY FACTOR (DOLLARS/QUERY)
   DIN,R,29/DUT,R,30
REVGL    26.2  C  REVENUE GOAL (QUERIES/WEEK/STAFF)
   ECHR,A,26/DUT,R,30
REVIX    48    A  REVENUE INDEX (DIM. LESS)
   ECHR,A,26
S         9    L  STAFF (STAFF)
          9.1  N
   LR,R,10/AH,A,20/DH,A,21/DUT,R,30/IAP,A,36/ASM,A,37/AVS,A,
     50/PLOT,51.4/PRINT,51.8
SAR      40    L  TOTAL NO. OF ANSWERED QUERIES (QUERIES)
         40.1  N
   PRINT,51.9
SER      41    L  TOTAL NO. OF USERS (USERS)
         41.1  N
   PRINT,51.9
SN       50.6  C  INITIAL NO. OF STAFF
   S,N,9.1
SPQR      4.2  C  STAFF PRODUCTIVITY (QUERIES/WEEK/STAFF)
   AR,R,3/ISP,A,33
SRVIX    42    A  SERVICE INDEX
   GWR,R,47
STRA     50.1  C  SMOOTHING TIME FOR REVENUE ASSESSMENT
                    (WEEKS)
   AVQR,A,49/AVS,A,50
TDXS     23.2  T  TABLE FOR DXS
   DXS,A,23
TECHR    26.1  T  TABLE FOR ECHR
   ECHR,A,26
TEDDER   19.1  T  TABLE FOR EDDER
   EDDER,A,19
TEDDPQ   18.1  T  TABLE FOR EDDPQ
   EDDPQ,A,18
TEDDSF   24.1  T  TABLE FOR EDDSF
   EDDSF,A,24
TEEC     27.1  T  TABLE FOR EEC
   EEC,A,27
TEMAER   39.1  T  TABLE FOR EMAER
   EMAER,A,39
TEMPER    8.1  T  TABLE FOR EMPER
   EMPER,A,8
TEQAAR    4.1  T  TABLE FOR EQAAR
   EQAAR,A,4
TIME     50.9  N
TOJ      10.1  C  TIME ON JOB (WEEKS)
   LR,R,10
TR        6    R  TERMINATION RATE (USERS/WEEK)
   U,L,5/NER,A,43
TRN       6.1  C  TERMINATION RATE NORMAL(FRACTION/WEEK)
   TR,R,6
```

```
U           5   L  USERS (USERS)
            5.1 N
   QR,R,2/TR,R,6/ER,R,7/EMPER,A,8/ISM,A,34/ASTND,A,38/YPUG,A
      ,44/QPUG,A,45/PLOT,51.4/PRINT,51.8
UGN         7.1 C  USER GROWTH RATE NORMAL (FRACTION/WEEK)
   ER,R,7
UN         50.7 C  INITIAL NO. OF USERS
   U,N,5.1
UPT        13.1 C  USERS' PERCEPTION TIME (WEEKS)
   DDPU,A,13
YPUG       44   A  YEARLY PERCENTAGE GROWTH IN USERS
   PRINT,51.9
```

Concise model listing

```
ISS2.DYNAMO
00001 *   ISS2
00002 NOTE
00003 NOTE
00010 L   Q.K=Q.J+(DT)*(QR.JK-AR.JK)
00011 N   Q=QN
00020 R   QR.KL=U.K*PQ.K
00030 R   AR.KL=ASP.K*SPQR*EQAAR.K
00040 A   EQAAR.K=TABHL(TEQAAR,Q.K,0,0.02,0.005)
00041 T   TEQAAR=0/.1/.5/.9/1
00042 C   SPQR=10
00050 L   U.K=U.J+(DT)*(ER.JK-TR.JK)
00051 N   U=UN
00060 R   TR.KL=U.K*TRN
00061 C   TRN=0.02
00070 R   ER.KL=(U.K)(UGN)(EMAER.K)(EDDER.K)(EMPER.K)
00071 C   UGN=0.0374
00080 A   EMPER.K=TABLE(TEMPER,U.K/PU,0,1,0.2)
00081 T   TEMPER=1/1.05/1.1/1.05/.80/0
00082 C   PU=2000
00090 L   S.K=S.J+(DT)*(HR.JK-LR.JK)
00091 N   S=SN
00100 R   LR.KL=S.K/TOJ
00101 C   TOJ=200
00110 R   HR.KL=AH.K/PTME
00111 C   PTME=26
00112 NOTE
00113 NOTE DELIVERY DELAY ETC.
00114 NOTE
00120 A   DIX.K=Q.K/AR.JK
00130 A   DDPU.K=SMOOTH(DIX.K,UPT)
00131 C   UPT=13
00140 A   DDPP.K=SMOOTH(DDPU.K,PPT)
00141 C   PPT=26
00150 A   DDPF.K=SMOOTH(DDPU.K,FPT)
00151 C   FPT=40
00160 A   LDDPM.K=SMOOTH(DIX.K,LMPT)
00161 C   LMPT=26
00162 NOTE
00163 NOTE  EFFECTS OF DD
00164 NOTE
00170 A   PQ.K=PQN*EDDPQ.K
00180 A   EDDPQ.K=TABLE(TEDDPQ,DDPU.K/DDN,0,3,0.5)
00181 T      TEDDPQ=1.5/1.25/1/.8/.65/.57/.5
00190 A   EDDER.K=TABLE(TEDDER,DDPP.K/DDN,0,3,0.5)
00191 T   TEDDER=1.6/1.47/1/.47/.3/.3/.3
```

```
00192 NOTE
00193 NOTE LONG TERM DECISIONS
00194 NOTE
00200 A   AH.K=(DH.K*EDDSF.K)-EECHR.K*S.K
00210 A   DH.K=(ALR.K*PTME)+DXS.K*S.K
00220 A   ALR.K=SMOOTH(LR.JK,LMPT)
00230 A   DXS.K=TABLE(TDXS,LDDPM.K/LDDNM,0,3,0.5)
00231 C   LDDNM=0.5
00232 T   TDXS=-.2/-.15/0/.2/.35/.45/.5
00240 A   EDDSF.K=TABHL(TEDDSF,DDPF.K/DDN,1,3,0.5)
00241 T   TEDDSF=1/.75/.50/.40/.35
00250 A   EECHR.K=ECHR.K*EEC.K
00260 A   ECHR.K=TABHL(TECHR,REVGL/REVIX.K,1,1.5,0.1)
00261 T   TECHR=0/.08/.15/.20/.23/.25
00262 C   REVGL=8
00270 A   EEC.K=TABHL(TEEC,DF.K/NSUF,0,1,0.25)
00271 T       TEEC=1/.45/.20/.07/0
00280 L   DF.K=DF.J+(DT)*(DIN.JK-DUT.JK)
00281 N   DF=NSUF
00282 C   NSUF=15000
00290 R   DIN.KL=AR.JK*RECF
00291 C   RECF=10
00300 R   DUT.KL=S.K*REVGL*RECF
00301 NOTE
00302 NOTE ALLOCATION OF STAFF
00303 NOTE
00310 A   ASP.K=SMOOTH(DAP.K,ACT)
00311 C   ACT=2
00320 A   DAP.K=MIN(IAP.K,ISP.K)
00330 A   ISP.K=Q.K/(SPQR*DDNM)
00331 C   DDNM=0.5
00340 A   ISM.K=U.K*ANEED*NDBIAS
00341 C   NDBIAS=1
00350 A   IFP.K=ISP.K/(ISP.K+ISM.K)
00360 A   IAP.K=IFP.K*S.K
00370 A   ASM.K=S.K-ASP.K
00371 NOTE
00372 NOTE EFFECT OF MARKETING
00373 NOTE
00380 A   ASTND.K=U.K*ANEED
00381 C   ANEED=0.001
00390 A   EMAER.K=TABLE(TEMAER,ASTND.K/ASM.K,0,3,0.25)
00391 T   TEMAER=2/1.55/1.3/1.1/1/.81/.7/.62/.56/.5/.45/.42/.38
00392 C   DDN=0.5
00393 C   PQN=0.035
```

```
00394 NOTE
00395 NOTE   PERFORMANCE AND OPERATIONAL  MEASURES
00396 NOTE
00400 L   SAR.K=SAR.J+(DT)*(AR.JK)
00401 N   SAR=NSAR
00402 C   NSAR=0
00410 L   SER.K=SER.J+(DT)*(ER.JK)
00411 N   SER=NSER
00412 C   NSER=0
00420 A   SRVIX.K=EDDER.K*EMAER.K
00430 A   NER.K=(ER.JK-TR.JK)
00440 A   YPUG.K=(SMOOTH(NER.K,52))*(5200)/U.K
00450 A   QPUG.K=(SMOOTH(NER.K,12))*(1200)/U.K
00460 L   AGOWL.K=AGOWL.J+(DT)*(GWR.JK)
00461 N   AGOWL=NAGOWL
00462 C   NAGOWL=0
00470 R   GWR.KL=SRVIX.K
00480 A   REVIX.K=AVQR.K/AVS.K
00490 A   AVQR.K=SMOOTH(QR.JK,STRA)
00500 A   AVS.K=SMOOTH(S.K,STRA)
00501 C   STRA=26
00502 NOTE
00503 NOTE   INITIAL CONDITIONS AND CONTROL CARDS
00504 NOTE
00505 C   QN=1
00506 C   SN=3
00507 C   UN=50
00508 C   DT=.2
00509 N   TIME=NTIME
00511 C   NTIME=0
00512 C   LENGTH=0
00513 C   PLTPER=8
00514 PLOT   U=U/Q=Q,QR=O/S=S,ASP=%/ER=E
00515 PLOT   EDDPQ=1,EDDER=2,EMAER=3,EMPER=4(0,2)/
00516 X   DXS=X(-1,1)/EECHR=C,EDDSF=S(0,1)
00517 C   PRTPER=48
00518 PRINT  1)U/2)Q/3)S/4)QR/5)HR/6)ER
00519 PRINT  1)SAR/2)SER/3)EECHR/4)YPUG/5)QPUG/6)AGOWL
00521 RUN
```

IV. MODEL TESTING

Judging Model Validity

There is no established norm for judging model validity; model validity is a realtive matter and depends on the model purpose. One of the purposes of the present study is to explain the behavior of ISS's; the model will then have to be able to "reproduce" actual system behavior. For the comparison of simulation results and actual behavior it is common to apply statistical methods. Sometimes, however, this is not possible or desirable. Forrester discusses nonquantitative model validation (1961, pp. 128-129):

> "A model will be cast in numerical form in order that our statements will be specific and unambigous. Such statements, however, often arise from beliefs about relative magnitudes, limiting conditions, and probable consequences. The numbers that appear in such a model often do not derive in any analytical or statistical way from specific numerical data from the operating system.
>
> Quantitative validation of a model should be done when possible and when the anticipated results are expected to justify the cost and effort. However, if most of the content of a model is drawn from nonnumerical sources in the form of individual personal knowledge and verbal and written descriptions, the defense of the model will usually rest on the same kinds of knowledge."

In assessing the realism of the simulation results in Chapter two we used the approach discussed by Forrester.

Sensitivity Tests

The consequences of changes in parameter values must be tested to get an indication of the sensitivity of the model to such changes. To an extent this form of sensitivity analysis is done continously as the model is developed, and the result of these tests is that important parameters are identified, the values of which will have to be verified by empirical evidence before the model development can proceed. Some parameters will affect the simulation results little, and for these parameters it is not necessary to spend resources on obtaining e· ·rical evidence.

For the model ISS2, for example, the user growth rate normal UGN determines the speed of the overall growth development. It was therefore necessary to find some empirically based estimate for UGN as discussed on p. 116. Examples of parameters that do not affect the simulation results in any significant way are the users' perception time UPT and the potential users' perception time PPT. No further attempt was made to find estimates of these parameters.

It is not possible to test all combinations of parameters which is a limitation of the sensitivity tests:

> "Thus the modeler may miss a combination of parameters which will have a dramatic effect on conclusions. This danger is one disadvantage of simulation models compared to analytic models. Because of this limitation, the modeler must select those parameters for testing which his understanding of the system suggests are important, rather than try to test numerous changes in the hopes of finding one which will produce an important effect." (Shaffer, 1976, p. 300)

A simplified description of ISS2 can illustrate what parameters are important: the basic activity represented in ISS2 is the processing of queries, and the way the ISS manages this processing has direct effects on the rest of the ISS/user/funder system. The parameters that have a direct impact on the physical flow of queries largely determine the behavior of ISS2. These parameters are given in Figure 15 (the definitions of variables are given on p. 159 ff.).

In addition to pointing out needed empirical evidence, the sensitivity analysis can identify important decision variables. These variables are often not amenable to empirical validation since they represent policy options. However, by simulating changes in these variables it is possible to get a basis for policy analysis for the system.

The focus in the present study is on managerial decision making and therefore we have assumed a certain behavior on the part of the funder. We have consequently not regarded the parameters that determine staff, S, as possible decision variables, although they have a significant impact on the simulation results. The number of users, U, is the primary determinant of the query rate and the parameters that influence U are possible decision variables. The results of the tests of these parameters are given in the discussion in Chapter two (p. 84 ff.) where also the implications for managerial decision making are given.

Model Runs Discussed in Chapter Two

The figures in Chapter two were produced by running the model ISS2 with parameter values according to the following:

Figures 11-a and 11-b	length=240
Figure 12	length=240, ndbias=2
Figure 13	length=240, tedder= 1.5/1.3/1/.8/.6/.4/.3

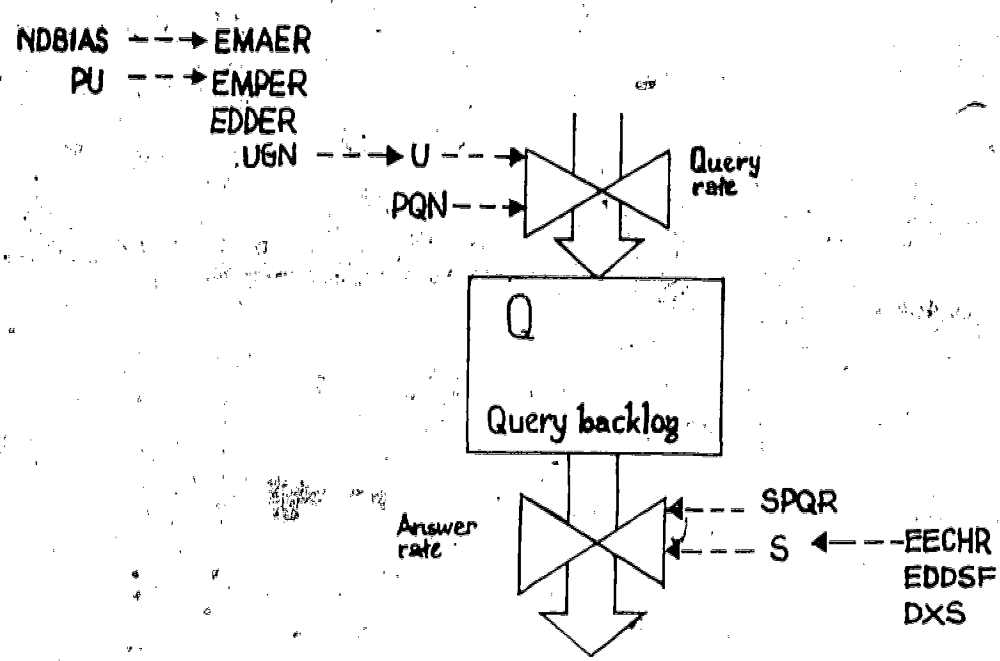

Figure 15
The flow of queries in ISS2.

The discussion of managerial decision making in Chapter two is based on the results of the following simulations with the final version of the model (the length of all runs is 240):

SN=1 and NSUF=5000

SN=2 and NSUF=10000

SN=2.5 and NSUF=12500

SN=4 and NSUF=20000

SN=10 and NSUF=10000

NDBIAS=2

NDBIAS=0.5

NDBIAS=1.2

NDBIAS=0.8

TEDDSF=1/1/1/1/1 and TECHR=0/0/0/0/0/0

ACT=12

ACT=24

ACT=5

TEDDER=1.6/1.25/1/.7/.4/.35/.3

TEDDER=1.5/1.3/1/.8/.6/.4/.3

TEDDPQ=1.25/1.1/1/.92/.85/.80/.75

TEDDPQ=1.75/1.55/1/.7/.55/.5/.5

TEDDPQ=2.15/1.4/1/.94/.88/.84/.82

TEDDPQ=2.15/1.4/1/.65/.45/.25/.15

TEDDPQ=2.5/1.56/1/.94/.88/.84/.82

PQN=0.02

PU=500

PU=770

PU=1200

PU=1500

PU=3000

PU=7000

CHAPTER FOUR
AN EXPLANATION OF THE COMING STAGNATION OF INFORMATION SEARCH SERVICES+

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An explanation of the coming stagnation of information search services

Mats G. Lindquist

Keywords: *Information search services, Systems analysis, Simulation studies, System dynamics*

Abstract: Analyses of the on-line search market have been subject to several serious misconceptions concerning the service retailers, i.e. the information search services (ISS). One of the consequences of this is that the ISS growth potential has been overestimated. The paper points out that, even if there is an overall growth in on-line searching, the individual ISSs will typically show a stagnation after just over two years. Since the average operative age of an ISS is about two years, it is possible that even the aggregate growth in the next few years will be less than the present. This decline in growth rate is not inevitable but likely.

1 Introduction

Information related activities are becoming increasingly important in our society, which seems to be becoming fundamentally information based[1]. In particular, the production, distribution and consumption of scientific and technological information have experienced an accelerated rate of growth, and there is no indication that the growth will slow down in the near future[2].

The overall annual growth rate in the information services market, i.e. the provision of search capabilities and data bases, has been estimated at 30%[3] with a projection of even higher growth in the future. On-line searching alone has grown dramatically; the volume of searches performed on the Lockheed system in 1973 was 20 times the 1970 figure, and in 1975 there were 150 times as many searches as in 1970[4]. The structure of the market for information search services, in terms of suppliers and distributors, also seems to have been stabilized around 1973-74[5].

Together, these developments could be the basis for expectations of growth for information search services, i.e. the information retailers whose customers are the end

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'........... our society .... seems to have changed into a fundamentally information-based one.'

users of the information. They are in a market where the only trend is growth. There is, however, something else that has to be taken into account, namely the lack of established knowledge of the ISS users and the market, a problem that was identified and emphasized in a 1974 study of research needs related to technical and scientific information[6].

2 Misconceptions regarding operational ISS

The insufficient knowledge about ISSs and their markets has led to some serious misconceptions which in some ways have hindered both proper learning and growth of operative ISSs. The most important misconceptions are discussed in the following Sections.

2.1 Age of ISS

The length of time a typical ISS has been operational is often overestimated. It is true that most search *systems* have been available since 1969-70, and a few even longer[7], but this must not be confused with the availability of the retailing search *service*. Of all the ISSs participating in the SDC impact study[8], about 44% had had access to the on-line systems for one year or less, and another 44% between one and three years. Considering, in addition, that the first year's operation is often less effective owing to substantial organizational adjustment efforts, we must conclude that ISS operation is still in its infancy.

2.2 Staff productivity

The number of searches a person can perform is often overestimated, which is particularly serious if the sponsor of the ISS bases his staffing decision on this estimate. The reason for the overestimation could be that there is a bias in the answers from searchers regarding search time per query, since a short search time would make computerized literature searches look more cost-effective. Survey answers might then be more ideal than real, meaning that the indicated search time does not include a reasonable overhead time. In an operational environment, overhead time is significant and includes administration, system breakdowns, scheduling delays, and other disturbances. The direct search time seems to vary greatly depending on the philosophy of the ISS: some services spend relatively little staff time per search, whereas others spend a great deal. One hour seems to be a typical search time, which is indicated by the SDC study[9]; but the very short time at the terminal (mean value 19.1 minutes; median value 15.3 minutes) reveals that the search requests must be of a relatively simple kind. The corresponding time for the NASIC

'........... we must conclude that ISS operation is still in its infancy.'

'The reliance on institutional funds or grants limits the population of potential users more severely than is commonly acknowledged.'

service at MIT is almost double (mean value 37 minutes)[10], and another ISS operating in a university and research environment, the Royal Institute of Technology IDC, gives an average search time of 2.9 hours[11]. The conclusion from this discussion is that, for an ISS operating in a research environment and dealing with relatively complex search requests, the number of searches per staff per week must be less than 20, and that a feasible long-run average is about 10.

2.3 Applicability of pricing policies

Considerable effort has been spent on discussions of ISS pricing policies. It is clear that price has some effect on the number of incoming search requests, but ISSs do not operate in a normal market economy. Until the cost for searching has come down to 10% or maybe 20% of today's cost, we cannot expect the end user to pay for the service out of his own pocket. The reliance on institutional funds or grants limits the

'We are in a position where we do not have as much experience as we think.'

population of potential users more severely than is commonly acknowledged.

2.4 Basis for system analysis

The applications of various system analysis techniques to aspects of ISS operation have been legion, but in general too little emphasis has been put on factors outside the ISS itself. In most ISS models, the representation of the users and their influence is too simplified. The most serious omission, however, is that of the influence of the sponsoring unit's actions[12]. An ISS model for managerial decision making must take into account the effects of both the users' and the sponsor's actions.

Frankly, we are in a position where we do not have as much experience as we think, we are less efficient than we like to think, our market is smaller than we think, and we do not take into account all the necessary factors when we analyze our problems.

3. Analysis of ISS growth

To get an idea of the future growth of individual ISSs, it is not sufficient to extrapolate trends, but it is necessary to make a more thorough study of the factors determing growth. It is also necessary to avoid misconceptions and omissions of important influences. Finally, it must be realized that what will happen to an individual ISS is not necessarily a scaled-down equivalent of what will happen in the information search industry as a whole; the service suppliers and the search services do different kinds of business.

By looking at the growth question from the viewpoint of the [illegible] ISS, we can construct a model [illegible] be a more relevant basis for prediction, and, by considering the factors discussed previously, we can also make more accurate predictions.

The simulation model ISS2[13] provides such an adequate basis for a discussion of where ISSs are heading. The model is of system dynamics type[14] and includes all the major feedback loops that affect the growth, in terms of number of users, of a typical ISS in an academic environment. The results of the system analysis and simulation runs with the model show that the hypothesized reference behavior (see Fig. 1) is indeed fully explainable with the variables chosen and is a consequence of the structure of the system, which includes both the users and the sponsor.

A prediction of stagnation for operative units in a market characterized by aggregate growth requires an explanation. The basic

'........... stagnation is .... not a mystery but a consequence of the activity in the system.'

'The decline in ISS growth rate is likely, but we might ask whether or not it is inevitable.'

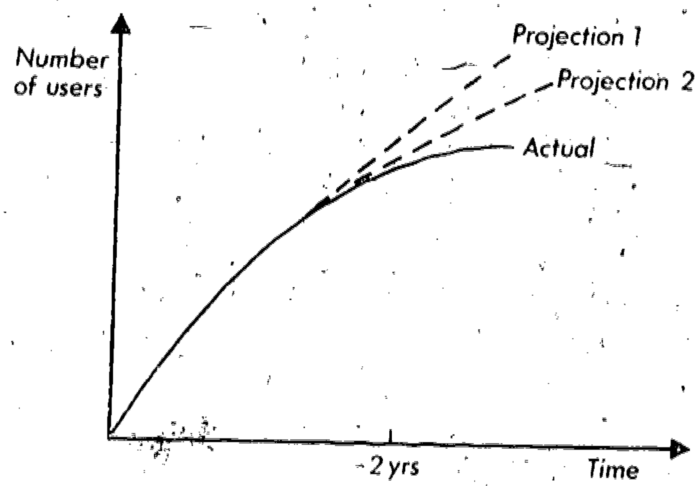

Fig. 1 *Typical development of the number of users of an ISS*

mechanism can be described by three causal loops (Fig. 2).

Loop 1 is typical for most business and service activities; as business volume goes up, expansion is needed and more resources acquired which can make it possible to handle more business. Loop 2 is the congestion loop. As business volume goes up, the fact that queues develop makes the service less attractive and discourages business. ISSs easily become congested, and at least part of the reason for this is a focus on search requests instead of users: capacity planning is done on basis of 'how many questions can we answer?' rather than 'how many users can we serve?' The point is that accepting a user should be a long term commitment. Until it is seen as such, we can say that too many users are admitted to the service. This, of course, would not be the case if the sponsor would expand the resources for the ISS quickly enough. However, the typical sponsor wants to be sure of an established need for more resources before he grants expansion (willing risk capital is indeed rare), but, by the time the need is established, there is already congestion, which also hinders expansion (loop 3). One reason for the latter effect is that the 'excess' number of users reduces the throughput, since the ISS staff is forced to spend time on user assistance, which will lower the revenue/cost ratio and activate economic concern on the part of the sponsor.

Fig. 3 shows the result of the computer simulation of ISS2.

4 Implications of the analysis

The simulation results will not be discussed in detail here, but their implications will be explored. They mean that the 'two years plus' stagnation is not a mystery but a consequence of the activity in the system. So stagnation should not be unexpected, and, when it occurs, it does not necessarily mean that the market is penetrated.

It is interesting to note that a similar stagnation was typical for SDI services. For these, stagnation did not occur until after about four years, a difference which could be a result of a larger market for the typical major service, and probably systemic differences between SDI and ISS services as well.

The reference run of the simulation model shows rapid initial growth. In about the second year, the annual growth rate is approximately 30%, and after that it declines to between 10% and 12%. The growth in search requests (queries) is slightly higher but follows the same pattern as the number of users. The estimated aggregate growth rate for the information search industry of 30% (see Introduction) is consistent with the simulation results, since the average age of existing ISSs is just over two years. In estimations of a likely ISS growth rate in the near future, the implication is that the typical ISS will stagnate but the annual average growth rate will stabilize somewhere around 10-12%.

The decline in ISS growth rate is likely, but we might ask whether or not it is inevitable. In principle it is not, for there are ways to influence the development and achieve a higher growth rate until market saturation is reached. Since problems well stated are half solved, we can look at the previous explanation for guidelines towards solutions. If the negative effects of congestion could be mitigated, higher growth would be achieved. Such an effect could be achieved either by a change in the link between congestion and business volume, or the link between con-

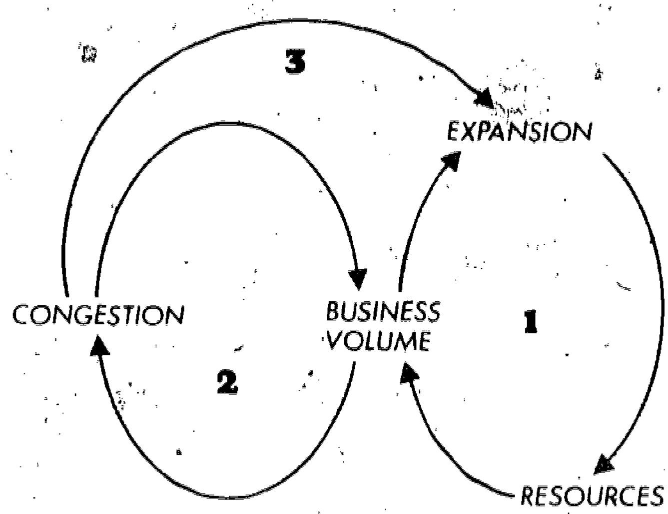

Fig. 2 *The Basic mechanism for ISS growth*

'Complex systems are typically insensitive to policy changes.'

gestion and expansion. Simulation runs with ISS2 verify this conclusion. The real-life meaning of these changes is greater tolerance to long response time on the part of users, and greater understanding and willingness to invest on the part of the funder, respectively.

There is an irrational feature of complex systems that make these possible higher growth rates less likely. Complex systems are, typically, insensitive to policy changes[15], it seems that such systems can seldom be made to exhibit a different behavior mode. At the same time, however, complex systems can show great sensitivity to even small changes in key parameters. For an ISS, one key parameter is the sponsor's willingness to invest, but current trends towards increased economic concern[16] does not encourage hope.

A different possibility for development

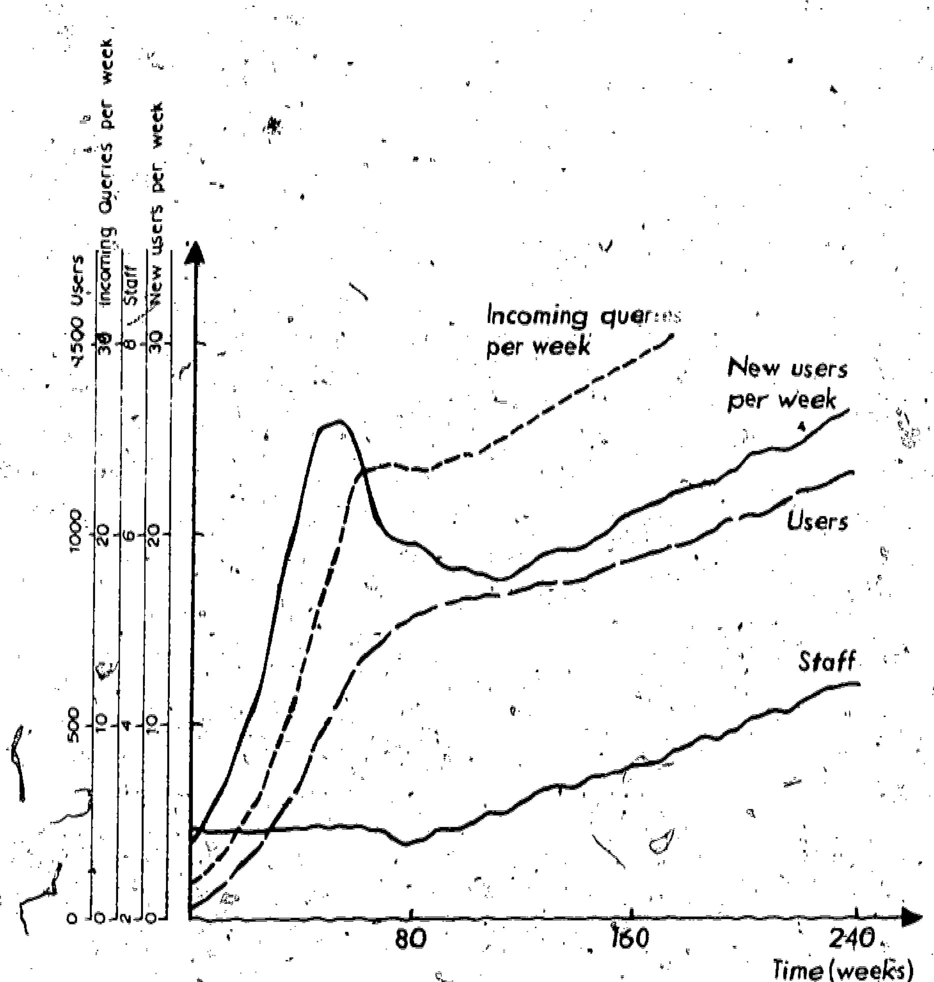

Fig. 3 *Result of simulation of ISS2*

that could invalidate our prediction is that of integration of ISSs and other information utilities. There is an academic consensus that an increase in service repertoire would give a substantially higher growth potential[17]. However, there is at present not much structure in the operative domain on which to build such a diversification.

5 Summary

The findings from the analysis discussed in this paper can be summarized as follows. The growth, in number of users, of a typical ISS in a research oriented environment, is characterized by initial rapid growth, a 'two years plus' stagnation and, following that, a slower growth of about 10-12% annually. Since existing ISSs are young, we can expect a stagnation in the coming years for the typical ISS. Unless new ISSs are established, there could be stagnation in the industry as a whole. The stagnation is not inevitable but likely.

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16 Stephan Schwarz: 'Information services to industry: the role of the technological university library, *J. Doc.*, 1976, 32, (1), pp. 1-16

17 Personal communication with D. Dunn, Stanford University, November 1976. An indication is also given by the increased attention to 'private files' as a service development, which is discussed in chapters of the annual review (see Reference 5) for the last two years

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